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Irrigation System Selection in an Energy-Short Economy

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ABSTRACT

Low pressure center pivot irrigation was the most energy efficient sprinkler irrigation system of the four sprinkler irrigation systems simulated for three representative types of Nebraska farms. Given 1978 and 1980 energy prices, natural gas was the least expensive fuel for powering the systems. Although an autogated pipe irrigation system proved most efficient in simulation, it is untried and is limited to fields adaptable to surface irrigation. Increased energy costs may force some irrigators to switch to dryland farming, convert to a less energy-intensive system, or irrigate with the present system and forego replacement if salvageability is too low.

Keywords: Irrigation, soil, energy, cropland

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CONTENTS

Page

SUMMARY

The low-pressure center pivot was the most energy efficient sprinkler irrigation system of the four sprinkler irrigation systems studied for use on three representative Nebraska farms. However, the center pivot system's increased application rate may result in runoff and erosion on steep slopes or on soils with low intake capacity.

Autogated pipe was the most energy efficient of all the simulated irrigation systems studied, but its relatively new technology is untried and its adaptability is limited to fields irrigable by surface irrigation.

Natural gas powered all irrigation systems at the least expense. Following in order of least expense were electricity, diesel fuel, and propane, using 1978 energy prices (price upturns since 1978 have made diesel the most expensive fuel).

Many of the simulated irrigation systems studied were too costly, possibly forcing producers to change systems, drastically cut irrigation, or discontinue irrigation altogether.

Some irrigators may increase returns by switching to dryland farming, converting to a less energy-intensive system, or if salvage value is too low, irrigating with the present system and foregoing replacement.

This simulation analysis considered three types of Nebraska farms:

* 160 acres in western Nebraska, semiarid and totally irrigated (the small farm).

* 640 acres in eastern Nebraska, humid continental, of which 320 acres are irrigated, 250 acres are dryland cropland, and the remainder is idle (the intermediate size farm).

* 6,000 acres in western Nebraska, semiarid, of which 320 acres are irrigated cropland, 320 acres are dryland cropland, and the remainder is rangeland (the large livestock farm).

The irrigation systems in the study were chosen because they are either the most commonly used in the United States or because they exhibit energy conservation potential. The systems are: ditch and siphon, gated pipe, and autogated pipe; center pivot, side-roll, and big gun sprinkler; and drip trickle.

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INTRODUCTION

The low-pressure center pivot irrigation system fueled by natural gas was the most energy efficient of the sprinkler irrigation systems studied on three representative Nebraska farms. This report addresses the quandary that farmers face in selecting irrigation systems in a period of rising energy costs and, at times, tight energy supplies. The analysis concentrates on decisions made at the farm level instead of at the crop enterprise or State and area levels. The analysis applies to most farm irrigation conditions in the northern Great Plains, and can also be applied to many southern Great Plains situations with adjustments in crop yields and water applications.

BACKGROUND

Selected irrigation systems for three simulated farm situations are identified to examine some of the relationships between the size and type of farm and the irrigation system selection criteria, response to rising energy costs, and power plant and irrigation system conversion potentials. The simulation analysis considered three types of Nebraska farms:

* 160 acres, totally irrigated, western Nebraska, semiarid (the small farm).

* 640 acres, eastern Nebraska, humid continental, of which 320 acres are irrigated, 250 acres are dryland cropland, and the remainder is idle (the intermediate size farm).

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The irrigation systems in the study were chosen because they are either the most commonly used in the United States or because they exhibit energy conservation potential. The systems are: ditch and siphon, gated pipe, and autogated pipe; center pivot, side-roll, and big gun sprinkler; and drip trickle.

The irrigation system performance measures used in the comparisons are assumed values based on other written material and on information obtained from irrigation specialists. Irrigation system performance varies with different levels of management or different irrigation situations.

This report provides information on the cost and energy tradeoffs that farmers must consider when selecting an irrigation system or converting an existing system. Water use, energy use, labor use, and capital use are all factors in the decisions faced by irrigators. The report also examines the impacts of rising energy costs on irrigated agriculture and evaluates some of the conversion alternatives considered by irrigators in response to rising energy costs.

Research is underway to expand the analysis in this paper by building a set of representative farm budgets for subareas of the Great Plains. Data in these budgets will be weighted by the estimated acres represented by the different types of farms and incorporated into area, State, and regional linear programing models. The models will be used to estimate aggregated changes in irrigated and dryland agriculture over time under alternative energy price and availability scenarios.

CRITERIA FOR SELECTED IRRIGATION SYSTEMS

The following irrigation systems are the most common in the area or are recently developed alternatives.

Surface Irrigation Systems

Surface irrigation systems usually apply water to the top of sloped fields and allow gravity to distribute the water across the field. The field must have the proper grade to distribute water evenly. The amount of water needed to push the water across the field varies with the field slope and the soil type. Surface irrigation systems generally have runoff water at the end of the field, which can be captured by a reuse pit, pumped back up to the top of the field, and recirculated. The reuse pit, pump, and return pipe constitute a reuse system.

The surface irrigation distribution systems selected are:

* Ditch and siphon--Uses a ditch to transport irrigation water to the field from either a surface water source such as a river or canal or a ground-water source. Siphon tubes draw the water from the irrigation ditch located at the top of the field and convey it over the side of the ditch and onto the field.

* Gated pipe--Uses a pipe to convey water from its source to sections of gated pipe which are installed at the top of the field. Gated pipe has a series of

adjustable openings which can be opened to allow the water to enter the field at various locations.

* Autogated pipe--Uses a set of electronically controlled valves to distribute water to sections of gated pipe which have been preset to handle the irrigation water.

Sprinkler Irrigation Systems

The sprinkler system is another basic type of irrigation distribution system. Sprinkler systems have been used for some time. But, use of the center pivot irrigation system and other traveling sprinkler systems has dramatically increased sprinkler irrigation. The sprinkler systems selected are:

* Center pivot--Has a stationary pivot point about which the system moves, mobile towers that support a pipeline and move the system around the field, and a pipeline that transmits water from the pivot point to the sprinkler heads which distribute water (fig. 1). Most center pivots irrigate approximately 130 acres. Center pivots vary from one manufacturer to another; however, the major difference among center pivots is the type and number of sprinkler heads used to distribute the water. The sprinkler heads affect the pressure and the application rate. This paper categorizes the center pivots by two pressure levels: high pressure, 75 $lb./in.^2$ g, (pounds per square inch gage), and low pressure, 45 $lb./in.^2$g.

* Side-roll--Has sections of pipe acting as the axle to a series of wheels which are propelled in a straight line across the field by a small gasoline engine (fig. 2). The water is supplied through a hose attached to the end of the system and must be shut off each time the side-roll is moved. Sets of sprinkler nozzles along the pipe distribute the water across the field. Side-roll systems normally irrigate about 40 acres; however, the acres irrigated per system vary considerably with the farm situation.

* Big gun--Uses a single large sprinkler nozzle mounted on a chassis and supplied with water by a large flexible hose (fig. 3). The sprinkler is propelled across the field by either a small gasoline engine or a water-drive mechanism. The single large rotating sprinkler head irrigates a large area around the sprinkler as the system moves through the field. Big gun sprinklers normally irrigate about 80 acres; however, the acres per system vary considerably with the farm situation.

Figure 1--Center pivot irrigation system

Figure 3--Big gun irrigation system

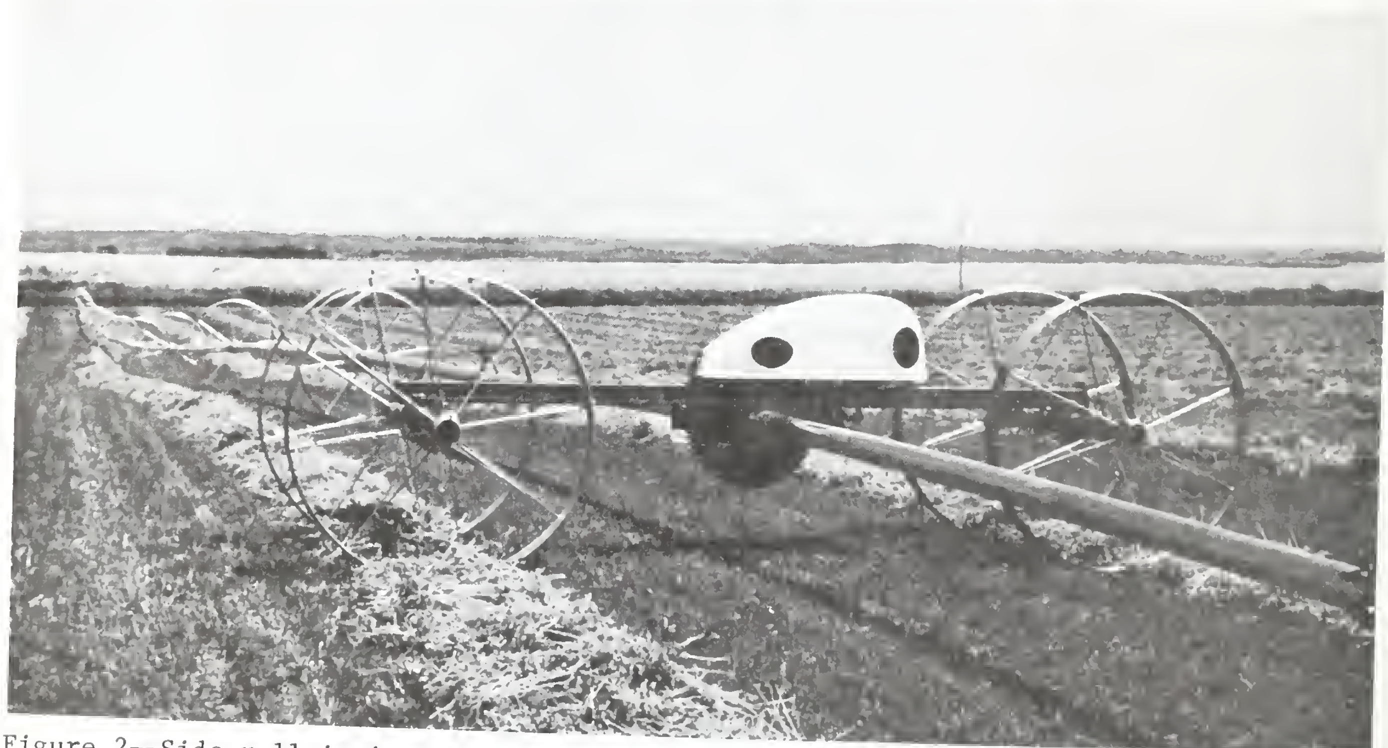

Figure 2--Side-roll irrigation system

Drip Trickle Irrigation System

Developed recently, it uses a set of underground or surface water lines with individual water emitters which allow irrigation of selected areas in a field. This type of irrigation system is particularly adaptable to widely spaced perennial crops, such as orchard crops where only individual trees need to be irrigated, helping to reduce the amount of irrigation water required as well as to minimize evaporation losses. This system is not readily adaptable to field crops and, therefore, is examined only briefly in this paper.

Field Irrigation Efficiency

Field irrigation efficiency is a measure of the amount of usable water added to the plant root zone as a percentage of total water applied to the field. Usable water excludes evaporation, runoff, and deep percolation beyond the root zone. Field irrigation efficiency varies considerably by type of system, management practices, and the environment in which irrigation takes place. Drip irrigation systems are highly efficient in their use of water since runoff, evaporation, and deep percolation can almost be eliminated. The systems are capable of achieving an irrigation efficiency of around 90 percent (9).1/ Sprinkler irrigation systems can also achieve high irrigation efficiencies (60 to 90 percent) since runoff and deep percolation can be minimized (9). Center pivot systems have efficiencies of around 85 percent (12). Gated pipe with reuse irrigation systems are approximately 75-percent efficient (7). An automated gated pipe system with reuse has attained irrigation efficiencies as high as 91 percent in field tests (7). Surface irrigation systems without reuse systems are about 60-percent efficient (28).

Factors such as commodity produced, soil type, lay of the land, and management techniques can cause considerable variability in irrigation efficiencies. For example, a 1978 study of the Green River Basin in Wyoming found irrigation efficiency averaging only about 30 percent, less than any of the irrigation system efficiencies in this study (23). The low irrigation efficiency in that area is due to the large amount of direct stream diversion of water onto native hay and improved haylands which have highly permeable soils. Most of the unconsumed water returns to the stream as return flow or through underground springs.

Another measure of irrigation system effectiveness is the uniformity of water distribution. Poor field irrigation efficiency may reflect a lack of uniform water distribution. For example, one end of a field may get too much water

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1/ Underscored numbers in parentheses cite references listed in the Bibliography.

resulting in water loss through deep percolation, while the other end of the field may receive too little water. Most surface water irrigation systems depend on water management techniques and labor to obtain uniform water distribution. The uniformity of sprinkler irrigation systems is often more a function of the initial engineering design of the system built to meet a specific field's needs than of the individual irrigator's water management.

Pumping Requirements

Pumping requirements vary among irrigation systems due to the different water pressures required and the different field irrigation efficiencies which affect the amount of water to be applied. The pressure requirements used for system comparisons are 10 lb./in.^{2}g for all gated pipe systems, 45 lb./in.^{2}g for side-roll and low-pressure center pivot systems, 75 lb./in.^{2}g for high-pressure center pivots, and 100 lb./in.^{2}g for big gun sprinklers. Pumping requirements also vary due to the lift required to raise the water from the well to the surface.

Pump efficiency also has a major impact on pumping requirements. Pump efficiency is the percentage of potential energy which is transformed into lifting water and putting it under pressure. A new pump can be assumed to be about 75-percent efficient (2). However, average field pump efficiency was estimated to be about 60 percent with variations ranging from under 40 percent to over 75 percent (20, 21). High pump efficiency should not necessarily be a goal in itself because the cost of maintaining a particular efficiency level may offset the energy cost savings.

Hathorn presents a hypothetical example of how to determine when to overhaul a pump (11). He compares the energy cost for irrigating 1 more year at a lower pump efficiency with the weighted average pump maintenance and energy cost for the life of the overhaul. Pump overhaul is economical when the cost of irrigating another year exceeds the weighted average. Thus, as energy costs rise, the pump efficiency at which pump overhaul is economically feasible will increase unless the cost of pump repair or replacement increases as rapidly as energy costs.

Energy Requirements

The estimated energy use in kilowatthour (kWh) equivalents per acre foot of water available for use by the crop is a measure of a system's energy requirement, reflecting variances in efficiencies of the pump drive mechanism, powerplant, irrigation system, and the total dynamic pumping head of the system. The total dynamic head includes both the pump lift in the well and the pumping head necessary to maintain the irrigation system pressure.

Operating energy use increases as the pumping lift and/or pressure increases and decreases as field irrigation efficiency increases. Low-pressure center pivot and side-roll sprinklers have higher pressure requirements than a ditch and siphon or a gated pipe system without reuse. But, the higher irrigation efficiencies of the center pivot and side-roll systems reduce the total water requirement, offsetting the additional energy per acre foot pumped due to the required system pressure. The low-pressure center pivot actually uses less energy than the ditch and siphon at a lift of 300 feet (table 1). Both the autogated pipe and the gated pipe with reuse system require less energy at 100 feet of pumping lift than a ditch and siphon system. At 300 feet of pumping lift, the drip trickle system requires the least energy of the systems compared in table 1. (The drip trickle system appears to be a very energy- and water-efficient system.)

Adaptability to Soils and Topography

Soil type, slope, and crops to be grown should all be considered when selecting an irrigation system for a particular location. Soils have different water intake rates, storage capabilities, and susceptibilities to compaction. Soils are grouped into 14 irrigation design groups in the Nebraska irrigation guide (24). Each of these design groups represents soils that have either different intake rates or different water storage capabilities. The Nebraska guide also divides the soils into different slope groups.

The Nebraska guide indicates that sprinkler irrigation systems are particularly suited to soils which have high intake rates, low soil moisture storage capabilities, and relatively steep slopes. Surface irrigation systems are more readily adapted to lower soil intake rates, larger soil moisture storage capabilities, and minimal slopes. By changing the rates and the amount of water applied, farmers can adapt certain irrigation systems to specific soil types. For example, shortening the length of run for a surface irrigation system will make the system better suited for soils with higher intake rates.

High water intake rates make it more difficult to attain either high field application efficiencies or uniformities of distribution with a surface irrigation system. Without proper management, high intake rate soils will have excessive deep percolation on the upper end of the field and dryness at the lower end due to the difficulty in moving the water across the field. Higher water flow rates and shorter lengths of runs must be used when irrigating high intake rate soils with a surface system. Surface irrigation systems are also limited to

Table 1--Estimated energy requirements in kWh equivalents per acre foot of water available for crop consumptive use, distribution pressures, and field irrigation efficiencies, selected irrigation systems for three water supply sources 1/

Item	Unit	Ditch and siphon	Gated pipe without reuse	Gated pipe with reuse 2/	Autogated pipe with reuse 3/	Center pivot		Side-roll sprinkler 4/	Big gun 4/	Drip trickle
						High pressure	Low pressure			
Surface water delivered to field	1,000 kWh	0	5/0.07	5/0.08	5/0.06	0.47	0.33	0.34	0.65	0.09
Ground water 100-foot pumping lift	do.	.32	.36	.31	.27	.67	.53	.57	.88	.28
Ground water 300-foot pumping lift	do.	.95	.94	.78	.68	1.08	.94	1.04	1.34	.67
Distribution pressure 6/	lb/in^2	Gravity only	10	10	10	75	45	45	100	20
Field irrigation efficiency 7/	percent	55	60	75	85	85	85	75	75	90

1/ Pump efficiency is assumed to be 65 percent. The powerplants are assumed to be electric, operating at 90-percent efficiency.

2/ The reuse system is assumed to recirculate 35 percent of the water applied. A 1-percent grade for a quarter mile was used to estimate the feet of lift.

3/ The reuse system is assumed to recirculate 25 percent of the water applied. A 1-percent grade for a quarter mile was used to estimate the feet of lift.

4/ The energy usage of these gasoline powered drive systems was converted to kWh equivalents.

5/ Gravity pressure available may be adequate in some cases, thus reducing energy needs.

6/ Distribution pressure requirements will vary with field topography. Rolling terrain will require higher pressure to distribute water evenly.

7/ Irrigation efficiency for any method varies considerably with the character of the field irrigated and the management.

fields with very little slope due to erosion on slopes of more than 2 or 3 percent depending on the soil type and crop.

Sprinkler irrigation systems are more versatile. However, the rate of application may be excessive for low intake rate soils with a large slope and may cause runoff. The large droplet size produced by some sprinklers may result in soil compaction early in the irrigation season before crop canopy development.

Labor Requirements

Labor requirements are often instrumental in deciding which type of irrigation system to use. Irrigators may select a system that requires very little labor to avoid hiring during the irrigation season. The irrigator's decision may be based less on the cost of additional labor than on the lack of experienced irrigation laborers. Thus, the irrigator may attempt to keep the total monthly labor requirements of the farm within the capability of the family labor supply.

Labor requirements of the irrigation systems vary considerably. The estimated labor requirements in hours of labor required per acre foot of water applied were derived from budgets or based on irrigation specialists' estimates (3). The irrigation labor requirements are distributed throughout the irrigation season by multiplying the hours of labor per acre foot by the monthly irrigation water requirements. In this study, the labor required to make and clean ditches for a ditch irrigation system or to set up the irrigation distribution system was not estimated separately. Thus, the early spring labor requirements are understated and the later summer needs somewhat overstated.

The estimated labor requirements per acre foot of water applied are:

1.2	hours for ditch and siphon
1.2	hours for gated pipe
1.2	hours for side-roll sprinkler
1.4	hours for big gun sprinkler
.4	hours for center pivot sprinkler
.6	hours for automatic gated pipe

These labor coefficients can vary significantly depending on the specific irrigation situation. The number of sprinkler units used, size and shape of the field, soil type, crop, level of management, age of the equipment, and well or surface water output rate could significantly change the labor requirements. However, the numbers used in this report are indicative of the average labor requirements per acre foot of water applied for one system relative to another.

Investment Costs

Irrigators must make a sizable initial investment in equipment, land preparation, and probably an irrigation well. The amount of land leveling, the cost of the well, the total acres irrigated per well, the powerplant, and the cost of bringing the energy source to the powerplant are the major factors that vary by irrigation situation. The irrigator is also limited in irrigation system and energy source selection by the adaptability of the land and the availability of various energy sources.

In 1978, investment costs per acre for the irrigation systems compared in this paper varied from $153 for the ditch and siphon to $312 for autogated pipe with reuse (table 2). The cost of a well and an electric powerplant increased the cost of the sprinkler systems more than the surface system since the higher pressures required raised the horsepower requirements. The cost of installing the power lines varied considerably due to the differences in the amount of wire which must be run from an existing power source to the pump. Also, the policies of electric power companies differ as to what percentage of the installation cost must be borne by the irrigator. Initial electrical line installation costs were estimated to range from zero to more than $5,000, according to some Nebraska power companies.

Irrigators must not only evaluate the initial investment cost but also the life expectancy of the various components of a system. Irrigation wells have an estimated life of 25 years, pumps 18 years, sprinkler systems 15 years, reuse systems 25 years, gearheads 18 years, and pipe 15 years (3). The life expectancies of power units are estimated to vary from 9 years for natural gas or propane powerplants to 25 years for electric powerplants.

Irrigation selection must be based on expected production costs and returns for the next 10 to 25 years. Salvageability of the equipment is limited; much of the initial investment is immobile and can only be recaptured by selling the land itself.

ADAPTABILITY OF SELECTED IRRIGATION SYSTEMS TO FARM SITUATIONS

Farm budgets are used to compare the costs and returns and labor use for selected irrigation systems, pumping lifts for water, and energy sources. The monthly labor requirements identify months when the total labor requirement for the farm exceeds the estimated labor supply of a family farm. The farm operator is assumed to work 60 hours per week during peak months and family labor is assumed to provide an equivalent of 30 hours per week during peak months. All farm labor requirements up to 360 hours per month can, therefore, be provided by farm family labor. Hired labor is not included (except for sugar beet weeding and thinning, a custom operation

Table 2--Investment costs for selected electric powered irrigation systems, 1978 1/

Item	Unit	Ditch and siphon	Gated pipe without reuse	Gated pipe with reuse	Auto-gated pipe with reuse	Center pivot		Side-roll sprinkler	Big gun sprinkler
						High pressure	Low pressure		
Area irrigated	acre	100	100	100	160	135	135	80	160
Land preparation cost (leveling)	dollars	15,000	15,000	15,000	24,000	1,500	1,500	750	1,500
Distribution system 2/	do.	300	5,400	5,400	22,800	28,500	28,500	15,950 (two units)	27,100 (two units)
Reuse system	do.	NA	NA	5,600	3/	NA	NA	NA	NA
Reuse pit	do.	NA	NA	3,500	3,200	NA	NA	NA	NA
Total	do.	15,300	20,400	29,500	50,000	30,000	30,000	16,700	28,600
	dollars/acre	153	204	295	312	222	222	209	179
Number of wells	number	1	1	1	1	1	1	1	1
Estimated well cost at 150-foot depth	dollars	3,800	3,800	3,800	3,800	3,800	3,800	3,800	3,800
Estimated pump cost for 100-foot lift	do.	4,500	4,500	4,500	4,500	5,200	5,000	5,000	5,200
Estimated electric powerplant cost 4/	do.	2,600	2,600	2,600	2,600	3,000	2,600	2,600	3,000
Total	do.	26,200	31,300	40,400	60,900	42,000	41,400	28,100	40,600
	dollars/acre	262	313	404	381	311	307	351	254

NA = Not applicable.

1/ Based on Nebraska data from distributors and from (3).
2/ Includes pipe from well to system.
3/ Included in distribution system cost.
4/ Not including charge to connect powerplants to the power source.

on the small farm). Returns for these budgets represent returns to labor, land, management, and risk.

The farm budgets use representative parameter values (tables 3 through 6). Five-year average Statistical Reporting Service crop yields are used, although a potential understatement of irrigated crop yields exists due to the possible inclusion of data from crops receiving only partial irrigation. Water application rates used in this report are based on crop consumptive needs (27). The crop consumptive needs for each month are divided by the irrigation system's field irrigation efficiency to estimate the amount of water which must be applied each month to meet all crop requirements.

The interaction of irrigation system characteristics and farm characteristics for the selected irrigation systems and the small, intermediate size, and large livestock farm situations reflects differences in farm returns, labor shortages, cropping limitations, irrigation efficiency impacts, and fuel cost sensitivity. For example, the large farms encounter labor limits, the side-roll system cannot be used for corn, and all are affected by irrigation efficiency, pump lift, and fuel costs.

Small Farm

The small farm has 80 acres of irrigated corn and 75 acres of irrigated sugar beets. Enterprise budgets are developed for each crop (table 7). The example enterprise budgets for a gated pipe with reuse irrigation system and two wells with 100-foot pumping lifts present a complete breakdown of the input costs with the irrigation costs identified. Irrigation fixed and variable costs amount to $5,555 and $3,839, respectively. The cost and returns for selected irrigation systems, pumping lifts, and energy sources are estimated by enterprise budgets and summarized to facilitate the irrigation system comparisons.

Costs and Returns

The ditch and siphon/surface water fixed and variable irrigation costs are lower than those for ground water since no water is pumped (fig. 4). The autogated pipe system has the lowest fuel and lubrication cost when pumped water is used (fig. 4 and app. tables 1-8). Variation in the fuel and lubrication costs among the different surface systems is greater for the 300-foot pumping lift than for the 100-foot pumping lift. More energy is required to raise each acre foot of water the additional 200 feet; thus, any reductions in water requirements attained by the more efficient systems result in greater energy savings. The energy cost savings obtainable for the 100-foot pumping lift situation are offset by the additional investment in irrigation equipment resulting in lower returns (fig. 5). There is very little difference in the total cost of irrigating with the different irrigation systems at the 100-foot pumping

Table 3--Estimated parameter values used for selected farm comparisons 1/

Item	Unit	Ditch and furrow	Gated pipe without reuse	Gated pipe with reuse 2/	Auto-gated pipe with reuse 3/	Center pivot		Side-roll sprinkler	Big gun sprinkler
						High pressure	Low pressure		
Area irrigated	acre	100	100	100	160	135	135	80	160
Total investment 4/	dollars	26,200	31,300	40,400	60,900	42,000	41,400	28,100	40,600
Distribution pressure 5/	$lb./in.^2$	Gravity only	6/10	6/10	6/10	75	45	45	100
Field irrigation efficiency 7/	percent	55	60	75	85	85	85	75	75
Labor use per acre-inch 8/	hours	.1	.1	.1	.05	.033	.033	.1	.12

1/ Pump efficiency is assumed to be 65 percent. The powerplants are assumed to be electric, operating at 90-percent efficiency.
2/ The reuse system is assumed to recirculate 35 percent of the water applied. A 1-percent grade for a quarter mile was used to estimate the feet of lift.
3/ The reuse system is assumed to recirculate 25 percent of the water applied. A 1-percent grade for a quarter mile was used to estimate the feet of lift.
4/ Investment costs vary by water source and fuel type. These estimates assume that a 100-foot well with an electric powerplant is used.
5/ Distribution pressure requirements will vary with field topography. Rolling terrain will require higher pressure to distribute water evenly.
6/ Gravity pressure available may be adequate in some cases, thus reducing energy needs.
7/ Irrigation efficiency for any method varies considerably with the character of the field irrigated and the management.
8/ Labor use may also vary considerably.

Table 4--Current normalized commodity prices

Item	Units	Normalized prices
		Dollars/unit
Commodity:		
Corn for grain	bu	2.34
Sugar beets	ton	30.58
Soybeans	bu	5.88
Grain sorghum	do.	2.16
Alfalfa hay	ton	46.30
Wheat	bu	3.00
Pasture	(AUM) 1/	12.00

1/ Animal unit month (AUM).

Sources: U.S. Department of Agriculture. Republican River Basin, Nebraska, Water and Related Land Resources Study Report. Economics, Statistics, and Cooperatives Service, Lincoln, Nebr., 1978, and U.S. Water Resources Council, "Agricultural Price Standards," Guideline 2, October 1978.

Table 5--Crop yields for selected western and eastern Nebraska farms 1/

Item	Units	Yield	
		Eastern Nebraska	Western Nebraska
Irrigated:			
Corn for grain	bu	112	93
Sugar beets	ton		20
Alfalfa hay	do.		3.6
Dryland:			
Corn for grain	bu	53	
Soybeans	do.	27	
Grain sorghum	do.	59	
Fallow wheat	do.	0	31
Pasture 2/	AUM	0	.3

1/ Crop yields represent 5-year averages obtained from 1974-78 Statistical Reporting Service data.
2/ Pasture yield from (25).

level. However, at the 300-foot pumping lift the energy cost savings by the more efficient systems are great enough to produce noticeable reductions in the total cost and significant increases in returns.

Natural gas was the least expensive source of energy for both the 100- and 300-foot pumping lifts. Electricity had the next lowest cost followed by diesel and propane. The large difference in returns by fuel type for the 300-foot pumping

Table 6--Estimated input costs for 1978 and 1980

Item	Unit	1978 costs	1980 costs
		Dollars	
Input costs:			
Gasoline	gal	0.63	0.95
Diesel	do.	.48	.95
Electricity	kWh	.041	.065
Natural gas	mcf	1.41	1.80
Propane	gal	.36	.43
Nitrogen (liquid or dry)	lbs	.22	.22
Anhydrous ammonia	do.	.14	.12
Phosphate	do.	.22	.25
Nitrogen, phosphate, potassium	do.	.11	.15
Herbicide (sorghum)	acre	2.00	2.50
Herbicide (corn)	do.	4.75	6.00
Herbicide (soybean)	do.	5.25	7.50
Herbicide (sugar beets)	lbs	.57	.70
Insecticide	acre	1/5.00	8.00
Nematocide	lbs	4.40	5.20
Fungicide (powdery mildew)	acre	9.50	7.50
Inoculant	do.	.75	.30
Interest rate on operating capital	dols	.09	.11
Other labor	hour	2.50	3.00

1/ In 1978, the charge for insecticide was $5 in western Nebraska and $7.50 in eastern Nebraska.

Sources: "Estimated Crop and Livestock Production Costs, Nebraska," University of Nebraska, Lincoln, and Agricultural Economics Extension Staff, 1978 (Report no. 80) and 1980 (EC 79-872).

Table 7--Annual crop enterprise costs related to 160-acre irrigated farm, gated pipe with reuse, 100-foot well, electric power

Item	Corn for grain costs		Sugar beet costs		Total cost
	Per acre	Total	Per acre	Total	
			Dollars		
Variable costs:					
Seed	16.80	1,344	11.90	892	2,236
Nitrogen or anhydrous ammonia	21.00	1,680	14.00	1,050	2,730
Phosphate	13.20	1,056	22.00	1,650	2,706
Insecticide	5.00	400	0	0	400
Herbicide	4.75	380	4.00	300	680
Nematocide	0	0	57.20	4,290	4,290
Chemicals	0	0	9.50	713	713
Tractor fuel and lube	5.82	466	6.91	518	984
Tractor repairs	2.53	202	3.20	240	442
Equipment fuel and lube	2.05	164	5.44	408	572
Equipment repairs	3.01	241	11.85	889	1,130
Irrigation fuel cost	17.95	1,436	24.35	1,826	3,262
Irrigation lube cost	.30	24	.41	31	55
Irrigation repair cost	2.87	230	3.90	292	522
Other labor	0	0	58.00	4,350	4,350
Custom combining	20.00	1,600	0	0	1,600
Interest on operating capital	4.31	345	9.43	707	1,052
Drying cost	5.01	401	0	0	401
Total variable costs	124.60	9,968	242.09	18,157	28,125
Fixed costs:					
Tractors	27.68	2,214	22.40	1,680	3,894
Machinery equipment	18.72	1,498	63.92	4,794	6,292
Irrigation equipment	30.56	2,445	41.47	3,110	5,555
Total fixed costs	76.96	6,157	127.79	9,584	15,741
Total costs	201.56	16,125	369.88	27,741	43,866
Net returns to land, labor, management, and risk 1/	40.07	3,206	241.72	18,129	21,335

1/ Net returns for corn includes 2 AUM of aftermath grazing. The estimated crop yields are 93 bushels per acre for irrigated corn and 20 tons per acre for irrigated sugar beets.

Figure 4

Annual Costs for Various Surface Water Irrigation Systems on a 160-Acre Farm Using Different Fuels, 100- and 300-Foot Pumping Depths, 1978

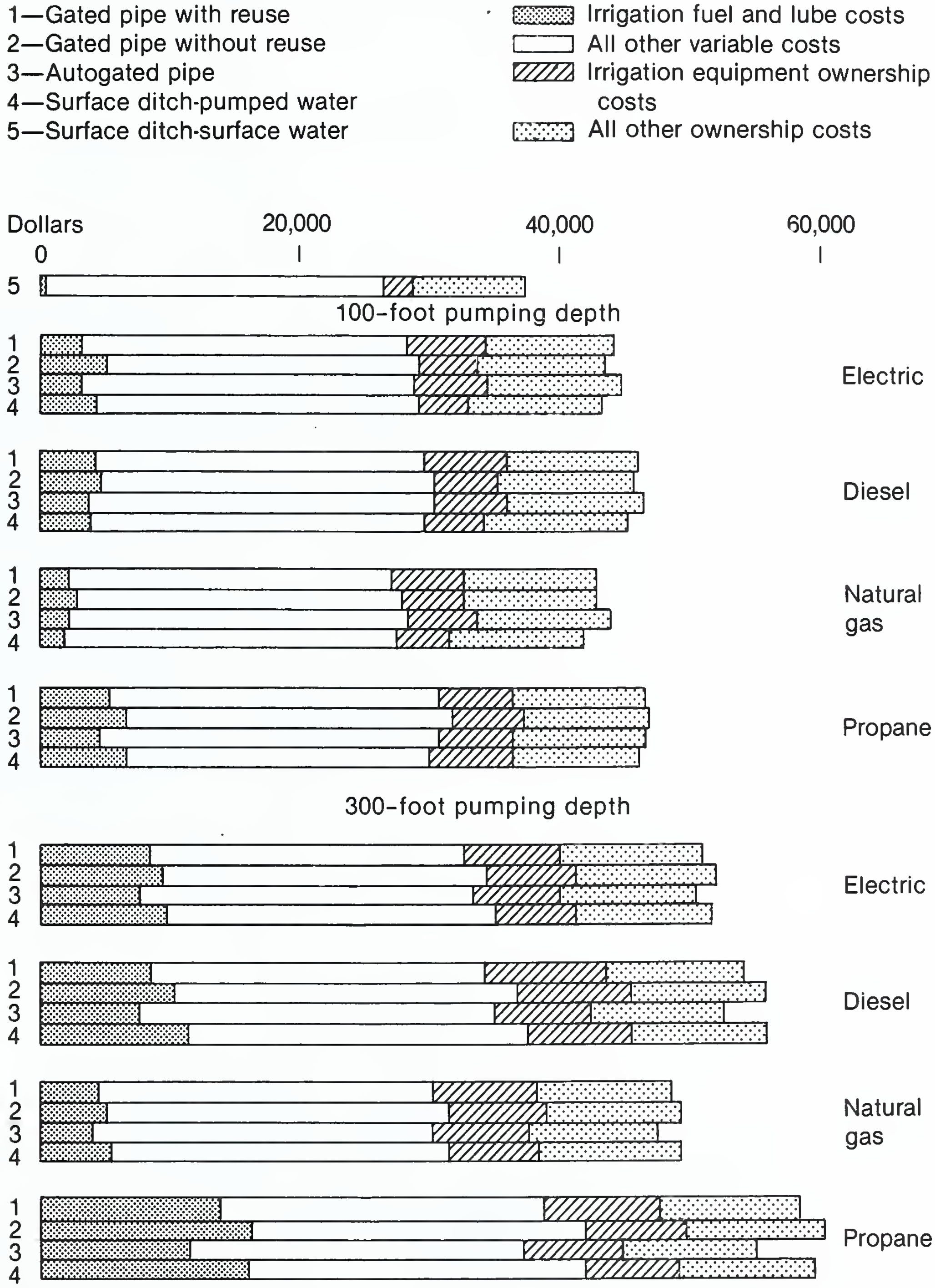
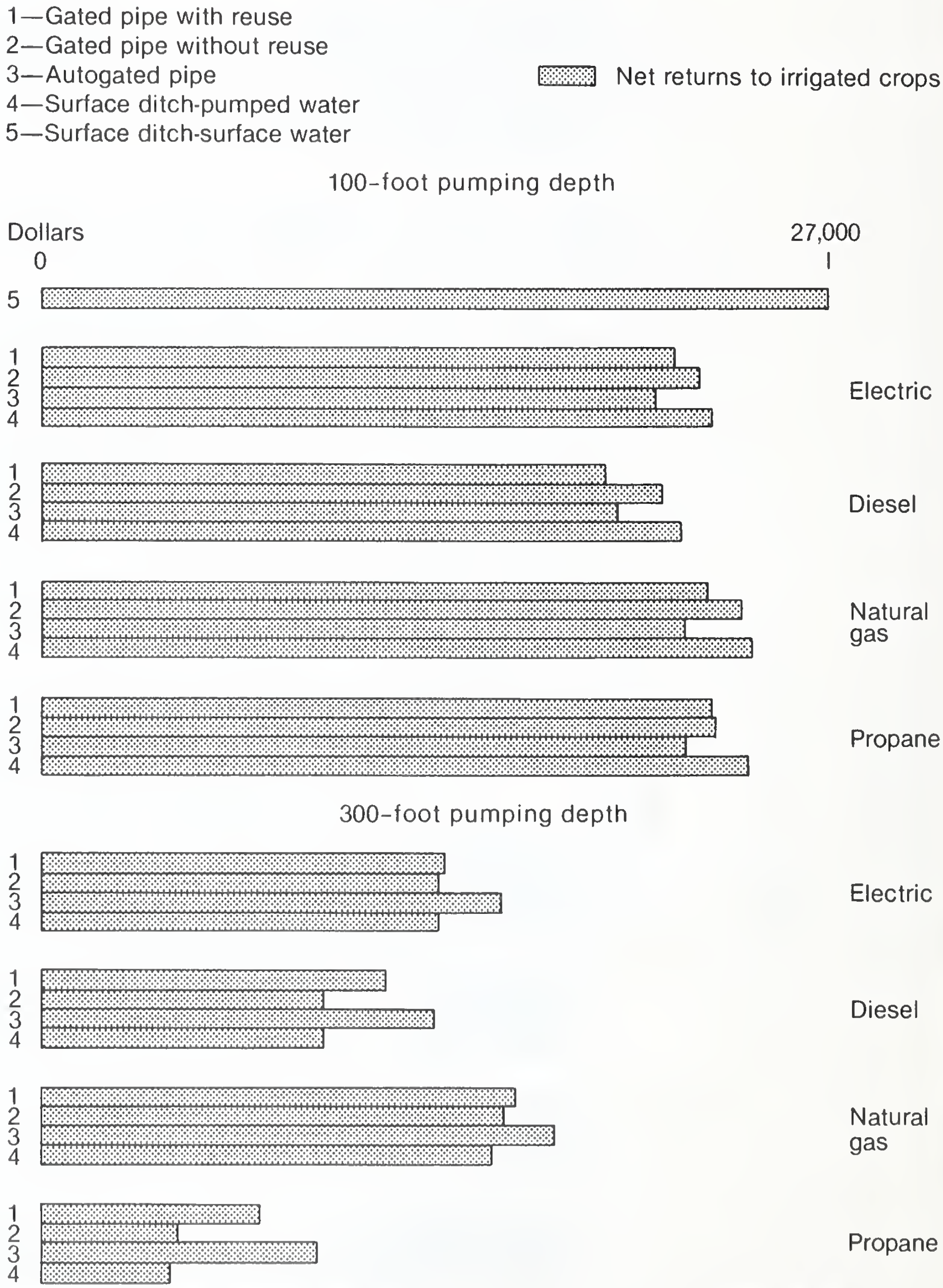


Figure 5

Returns to Land, Labor, Management, and Risk for Various Surface Water Irrigation Systems on a 160-Acre Farm, Using Different Fuels, 100- and 300-Foot Pumping Depths, 1978



lift indicates that irrigators are strongly affected by higher energy costs and higher pumping lifts. Note that the returns for the autogated pipe and the gated pipe with reuse system for the 300-foot pumping lift are not as strongly affected as the returns for the gated pipe without reuse and the ditch and siphon systems due to the formers' higher irrigation efficiencies.

Farm Labor Requirements

The peak labor requirement for the small farm is 214 hours in October (table 8). The next highest labor requirement is 189 hours of labor for the ditch and siphon system during the month of July. Both of these labor requirements are considerably less than the 360 hours of labor available from farm operators and their families. Thus, irrigation system labor requirements are not critical for the small farm. However, the operator of a small farm who is also employed off the farm may be restricted by labor availability.

Intermediate Size Farm

The intermediate size farm produces irrigated corn and dryland grain sorghum and soybeans. The acres of irrigated corn vary by system. The autogated pipe and the gated pipe with reuse systems irrigate 320 acres, the big gun systems irrigate only 310 acres of cropland for harvest due to the paths which must be left to allow the big gun to move up and down the field, and the center pivot systems irrigate only 270 acres with the remaining 50 acres in the corners of the 160-acre plots assumed to be planted to dryland corn.

The irrigated and dryland enterprise costs per acre, the total cost per enterprise for the farm, and the total farm costs for this farm with a gated pipe with reuse irrigation system are presented in table 9. The total cost per acre for the irrigated crop acres is three to four times as great as for dryland crop acres. However, the returns above total costs per acre for the irrigated crop acres are greater than those for the dryland crop acres (table 9).

Costs and Returns

The cost estimates for the alternative irrigation systems are based on only the irrigated acres (fig. 6 and app. tables 9-16). Thus, the costs for the high- and low-pressure center pivot systems are for only 270 acres. Since the costs are based on different acreages, a direct cost comparison is difficult. However, when the returns to dryland are added to the irrigated returns, the farm returns with the selected systems can be compared (fig. 7). The autogated pipe with reuse irrigation system has the highest returns, and the big gun system has the lowest returns.

Table 8--Labor requirements of small irrigated farm, 1978

Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Hours											
Machinery labor for:												
Corn for grain	5	5	5	20	119	28	22	5	5	5	71	5
Sugar beets	5	5	19	98	20	20	5	5	14	209	5	5
Total machinery labor	10	10	24	118	139	48	27	10	19	214	76	10
Irrigation labor for:												
Ditch and siphon (surface)--												
Corn	0	0	0	0	0	24	72	80	52	0	0	0
Sugar beets	0	0	0	0	0	52	90	90	64	0	0	0
Total	0	0	0	0	0	76	162	170	116	0	0	0
Ditch and siphon (pump)--												
Corn	0	0	0	0	0	24	72	80	52	0	0	0
Sugar beets	0	0	0	0	0	52	90	90	64	0	0	0
Total	0	0	0	0	0	76	162	170	116	0	0	0
Gated pipe without reuse--												
Corn	0	0	0	0	0	20	68	72	48	0	0	0
Sugar beets	0	0	0	0	0	45	83	83	60	0	0	0
Total	0	0	0	0	0	65	151	155	108	0	0	0
Gated pipe with reuse--												
Corn	0	0	0	0	0	16	56	56	40	0	0	0
Sugar beets	0	0	0	0	0	38	64	68	45	0	0	0
Total	0	0	0	0	0	54	120	124	85	0	0	0
Autogated pipe--												
Corn	0	0	0	0	0	8	24	26	18	0	0	0
Sugar beets	0	0	0	0	0	17	28	30	20	0	0	0
Total	0	0	0	0	0	25	52	56	38	0	0	0
Summary --total farm labor:												
Ditch and siphon (surface)	10	10	24	118	139	124	189	180	135	214	76	10
Ditch and siphon (pump)	10	10	24	118	139	124	189	180	135	214	76	10
Gated pipe without reuse	10	10	24	118	139	113	178	165	127	214	76	10
Gated pipe with reuse	10	10	24	118	139	102	147	134	104	214	76	10
Autogated pipe	10	10	24	118	139	73	79	66	57	214	76	10

Table 9--Crop enterprise costs related to the intermediate size cropland farm, gated pipe with reuse, 100-foot well, electric power, 1978

Item	Corn for grain costs		Dryland grain sorghum costs		Dryland soybeans costs		Total cost
	Per acre	Total	Per acre	Total	Per acre	Total	
	Dollars						
Variable costs:							
Seed	15.84	5,069	2.35	306	6.50	780	6,155
Nitrogen or anhydrous ammonia	19.60	6,272	11.20	1,456	0	0	7,728
Nitrogen, phosphate, potassium	11.00	3,520	0	0	0	0	3,520
Herbicide	4.75	1,520	2.00	260	5.25	630	2,410
Insecticide	7.50	2,400	0	0	0	0	2,400
Inoculant	0	0	0	0	.75	90	90
Tractor fuel and lube	4.46	1,427	4.20	546	3.06	367	2,340
Tractor repairs	2.60	832	2.41	313	1.84	221	1,366
Equipment fuel and lube	3.57	1,142	3.07	399	3.36	403	1,944
Equipment repairs	7.32	2,342	5.86	762	5.82	698	3,802
Irrigation fuel cost	17.68	5,658	0	0	0	0	5,658
Irrigation lube cost	.30	96	0	0	0	0	96
Irrigation repair cost	5.93	1,898	0	0	0	0	1,898
Drying cost	6.03	1,930	0	0	0	0	1,930
Interest on operating capital	4.04	1,293	1.20	156	1.00	120	1,569
Total variable costs	110.65	35,408	32.29	4,198	27.58	3,309	42,915
Fixed costs:							
Tractors	10.75	3,440	10.33	1,343	6.97	836	5,619
Machinery equipment	16.84	5,389	14.33	1,863	13.42	1,610	8,862
Irrigation equipment	34.86	11,155	0	0	0	0	11,155
Total fixed costs	62.45	19,984	24.66	3,206	20.39	2,446	25,636
Total costs	173.10	55,392	56.95	7,404	47.97	5,755	68,551
Net returns to land, labor, management, and risk 1/	118.98	38,074	94.49	12,284	110.79	13,295	63,653

1/ Net returns for corn include 2.5 AUM of aftermath grazing and for grain sorghum include 2 AUM of aftermath grazing. The estimated crop yields are irrigated corn, 112 bushels per acre; dryland grain sorghum, 59 bushels per acre; and dryland soybeans, 27 bushels per acre. The estimated yield for dryland corn is 53 bushels per acre.

Figure 6

Costs for Various Irrigation Systems on a 640-Acre Farm, Using Different Fuels, 100- and 300-Foot Pumping Depths, 1978

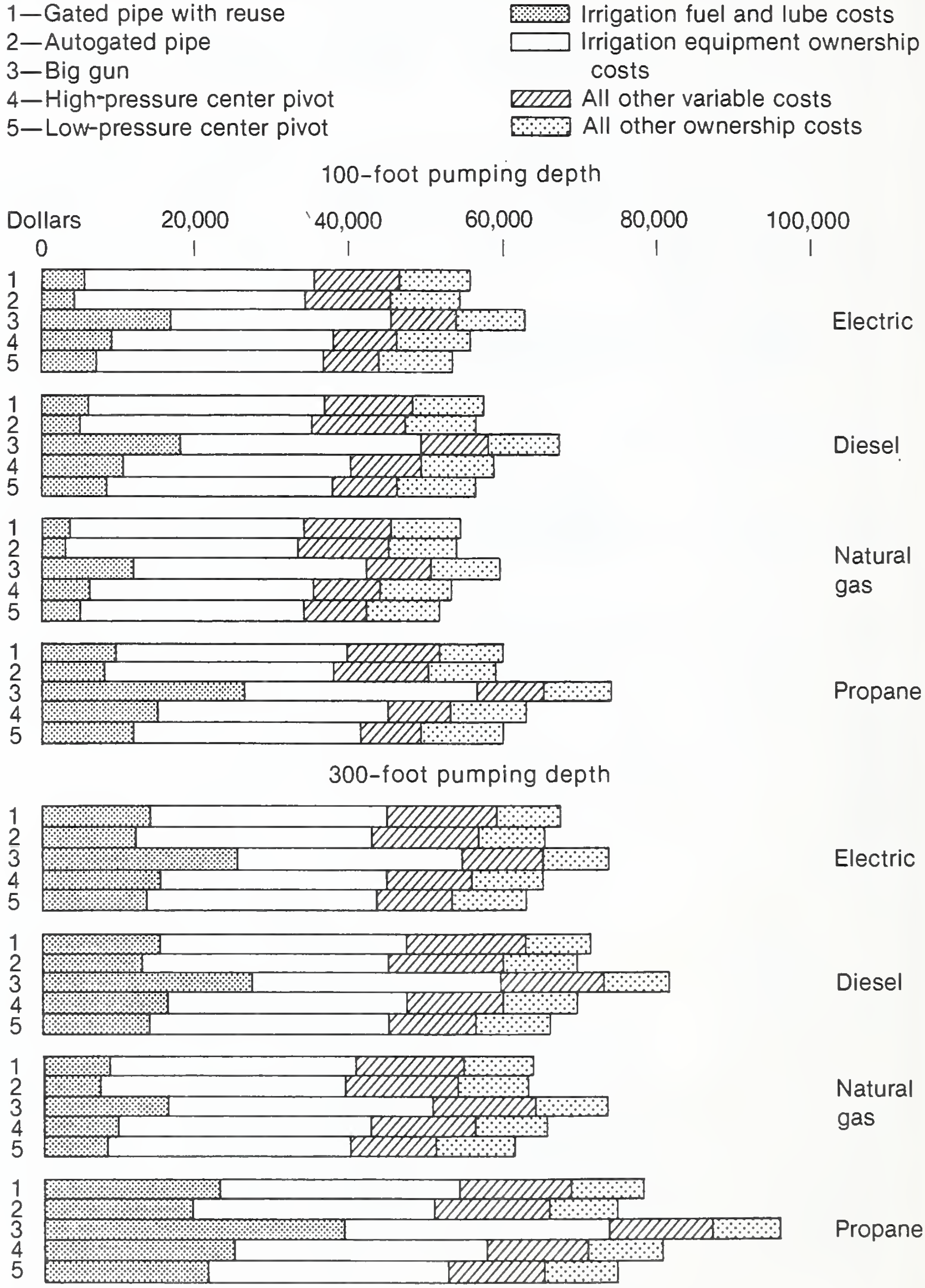
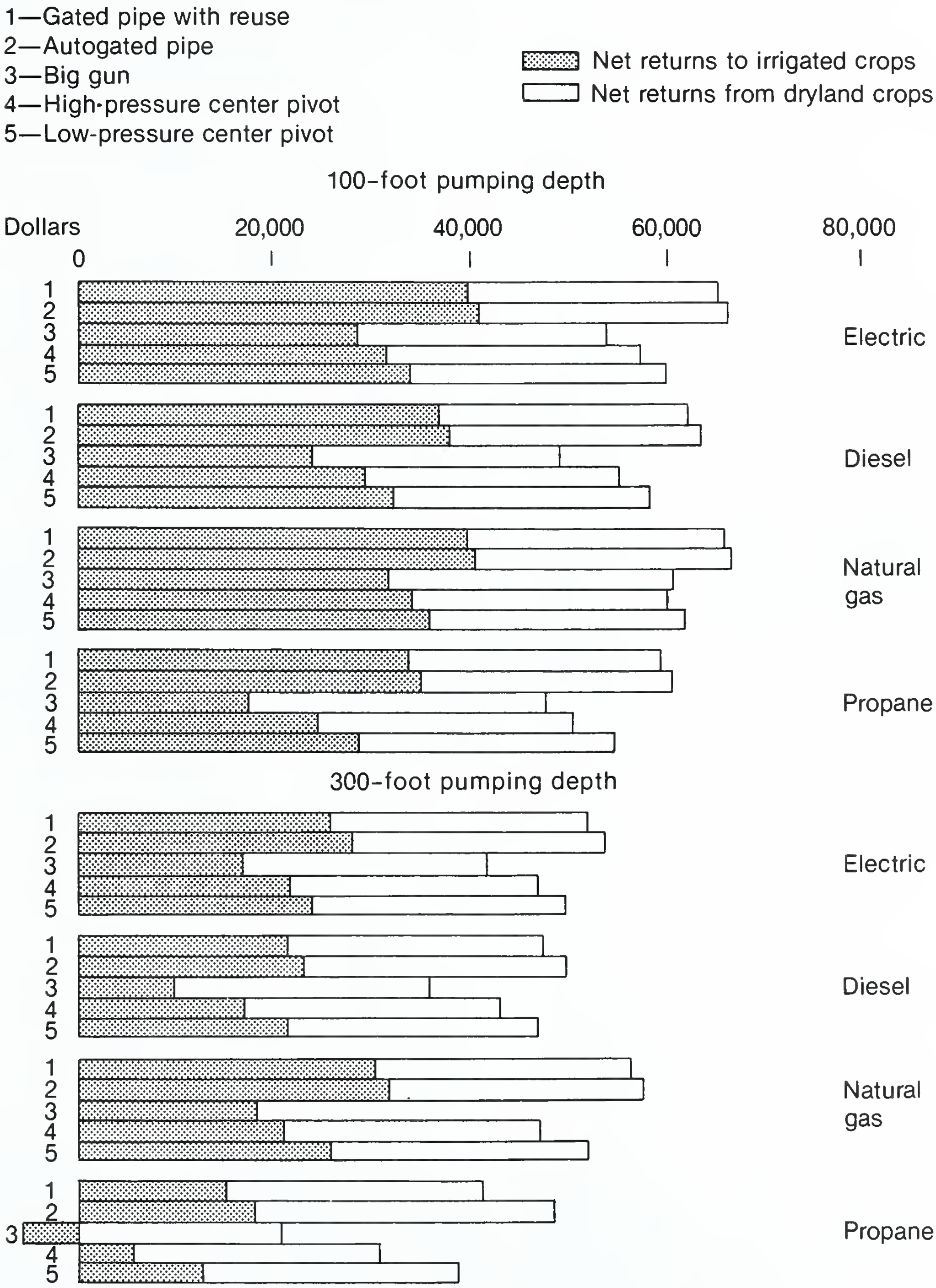


Figure 7

Returns to Land, Labor, Management, and Risk for Various Irrigation Systems on a 640-Acre Farm, Using Different Fuels, 100- and 300-Foot Pumping Depths, 1978



Farm Labor Requirements

The labor requirements for the intermediate size farm exceed the assumed available family labor of 360 hours either 2 or 3 months out of the year for every irrigation system (table 10). The labor requirements for May and November emanate from machinery operations other than irrigation. The excessive labor requirements in November could either be handled by hiring labor or by custom harvesting some of the crop. Labor requirements in July are excessive only for the gated pipe with reuse and the big gun irrigation systems. Although it appears that some of the labor requirements could be shifted to the preceding and following months, it is probable that some additional seasonal labor may be necessary in July, particularly for the big gun irrigation system. The family may also be able to supply this extra labor in some cases.

Labor requirements for the irrigation season--June, July, August, and September--are lower for the center pivot systems. This is partially due to the smaller amount of acreage irrigated; however, the center pivot is a labor efficient irrigation system. Farmers with less than 360 hours of family labor available may select this system in an effort to substitute capital for labor.

Large Livestock Farm

The large livestock farm has 160 acres of irrigated corn, 160 acres of irrigated alfalfa, 160 acres of dryland wheat, and 160 acres of summer fallow. The remainder of the ranch consists of pastureland. Returns from livestock for this farm were estimated on the basis of animal unit months per acre of pasture. Pastureland was estimated to have a nutritional value of 0.3 animal unit months per acre (25). An animal unit month was estimated to be worth $12 (26). The livestock were assumed to graze on pasture 9 months out of the year. It was estimated, based on these factors, that 178 cows and calves could be carried on this pastureland. The unirrigated corners, characteristic of center pivot irrigation, were assumed to remain pastureland and were not cultivated. This additional pastureland allowed the farm to support two additional cow-calf units. A western South Dakota ranch budget was used to estimate the monthly labor requirements per cow-calf unit because the Nebraska livestock budgets failed to identify the monthly labor pattern (1). Labor requirements for livestock production in western South Dakota and western Nebraska are similar because the climate and type of enterprise are similar.

The costs per acre for the irrigated crop enterprises using a gated pipe with reuse system are much higher than those for dryland fallow wheat; however, the irrigated returns are greater (table 11). The livestock returns are added to the total cropland returns.

Table 10--Labor requirements of the intermediate size farm, 1978

Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Hours						
Machinery labor for:												
Grain sorghum	8	8	8	25	88	65	49	8	8	153	8	8
Soybeans	7	7	7	23	60	46	46	7	7	138	7	7
Corn	22	22	22	74	252	140	141	22	22	22	577	22
Total machinery labor	37	37	37	122	400	251	236	37	37	313	592	.37
Corn irrigation labor for: 1/												
Gated pipe with reuse	0	0	0	0	0	64	208	224	160	0	0	0
Autogated pipe	0	0	0	0	0	22	96	96	70	0	0	0
High-pressure center pivot	0	0	0	0	0	14	54	54	40	0	0	0
Low-pressure center pivot	0	0	0	0	0	14	54	54	40	0	0	0
Big gun	0	0	0	0	0	74	242	260	186	0	0	0
Summary:												
Gated pipe with reuse	37	37	37	122	400	315	444	261	197	313	592	37
Autogated pipe	37	37	37	122	400	273	332	133	107	313	592	37
High-pressure center pivot	37	37	37	122	400	265	290	91	77	313	592	37
Low-pressure center pivot	37	37	37	122	400	265	290	91	77	313	592	37
Big gun	37	37	37	122	400	325	478	297	223	313	592	37

1/ Grain sorghum and soybeans are dryland crops on this farm.

Table 11--Crop enterprise costs for the large livestock farm, gated pipe with reuse, 100-foot well, electric power, 1978

Cost item	Alfalfa hay costs		Corn for grain costs		Dryland fallow wheat costs		Total cost
	Per acre	Total	Per acre	Total	Per acre	Total	
	Dollars						
Variable costs:							
Seed	0	0	16.80	2,688	2.56	819	3,507
Nitrogen or anhydrous ammonia	0	0	21.00	3,360	5.60	1,762	5,152
Phosphate	11.00	1,760	13.20	2,112	6.60	2,112	5,984
Herbicide	0	0	4.75	760	0	0	760
Insecticide	0	0	5.00	800	0	0	800
Baler twine-wire	1.65	264	0	0	0	0	264
Tractor fuel and lube	3.28	525	6.71	1,074	3.50	1,120	2,719
Tractor repairs	1.45	232	2.60	416	1.45	466	1,114
Equipment fuel and lube	1.95	312	2.93	469	3.92	1,254	2,035
Equipment repairs	3.81	610	4.56	730	4.20	1,344	2,684
Irrigation fuel cost	27.59	4,415	20.32	3,252	0	0	7,667
Irrigation lube cost	.49	66	.30	48	0	0	114
Irrigation repair cost	6.27	1,003	4.62	739	0	0	1,742
Drying cost	0	0	5.01	802	0	0	802
Interest on operating capital	4.32	691	4.36	698	2.29	733	2,122
Total variable costs	61.73	9,878	112.16	17,948	30.12	9,640	37,466
Fixed costs							
Tractors	11.17	1,787	28.19	4,510	9.26	2,963	9,260
Machinery equipment	12.65	2,024	35.23	5,637	32.36	10,355	18,016
Irrigation equipment	38.52	6,163	28.38	4,541	0	0	10,704
Total fixed costs	62.34	9,974	91.80	14,688	41.62	13,318	37,980
Total costs	124.07	19,852	203.96	32,636	71.74	22,958	75,446
Net returns to land, labor, management, and risk 1/	42.60	6,816	37.65	6,024	21.26	3,402	16,242
Net returns including livestock	0	0	0	0	0	0	35,462

1/ Net returns for corn include 2 AUM of aftermath grazing. The estimated crop yields are alfalfa hay, 3.6 tons per acre; corn for grain, 93 bushels per acre; and dryland fallow wheat, 31 bushels per acre.

Costs and Returns

Costs and returns for the irrigated acres for gated pipe with reuse, autogated pipe, and side-roll sprinkler irrigation systems are for 320 acres (figs. 8 and 9 and app. tables 17-24). The center pivot costs and irrigated crop returns are for 270 irrigated acres. Because the axis of the side-roll system is not high enough to clear the corn stalks, it is used to irrigate alfalfa only. The corn is assumed to be irrigated by autogated pipe.

The gated pipe with reuse system has the highest returns for all energy sources for the 100-foot pumping lift. The autogated pipe system has the highest overall returns for all energy sources except natural gas for the 300-foot pumping lift. Gated pipe with reuse is the system with the highest returns for natural gas powered systems with a 300-foot pumping lift. The natural gas powered alternative is the only one which has positive returns to land, labor, management, and risk from the irrigated cropland enterprises. The autogated pipe system uses less energy per acre foot of water available for crop consumptive use due to its higher irrigation efficiency. Thus, the irrigation fuel and lubrication cost is lower than that of the gated pipe with reuse system. However, the repair cost is higher for the autogated pipe system.

One reason for the switch in the relative returns of the autogated pipe and the gated pipe with reuse as fuel type changes is that the cost of energy as reflected in the irrigation fuel cost is less for natural gas than for electric, diesel, or propane power. This results in a smaller advantage for the more efficient autogated pipe system when using natural gas. The smaller fuel saving for natural gas is not enough to offset the higher repair costs.

Farm Labor Requirements

The total labor requirements for the large livestock farm exceed the 360 hours of family labor available per month for at least 3 months out of the year for every system (table 12). However, the center pivot systems only exceed the family labor available by 1 hour in April, 24 hours in May, and 67 hours in July. Although the family labor is exceeded, it is conceivable that the farmer may be able to make some adjustment in farm operations to shift some of the labor requirements to the preceding or the following months or work more hours than assumed in this analysis. The farmer could, therefore, operate the entire farm with the available family labor.

The autogated pipe system could also be operated by family labor if the total irrigated acres were reduced from the 320 assumed with the autogated pipe system to the 270 acres irrigated by the two center pivot systems. However, the gated pipe with reuse and the side-roll and autogated pipe

Figure 8

Costs for Various Irrigation Systems on the Large Livestock Farm, Using Different Fuels, 100- and 300-Foot Pumping Depth, 1978

1—Gated pipe with reuse
2—Autogated pipe
3—High-pressure center pivot
4—Low-pressure center pivot
5—Side-roll-alfalfa, autogated pipe-corn

Irrigation fuel and lube costs
Irrigation equipment ownership costs
All other variable costs
All other ownership costs

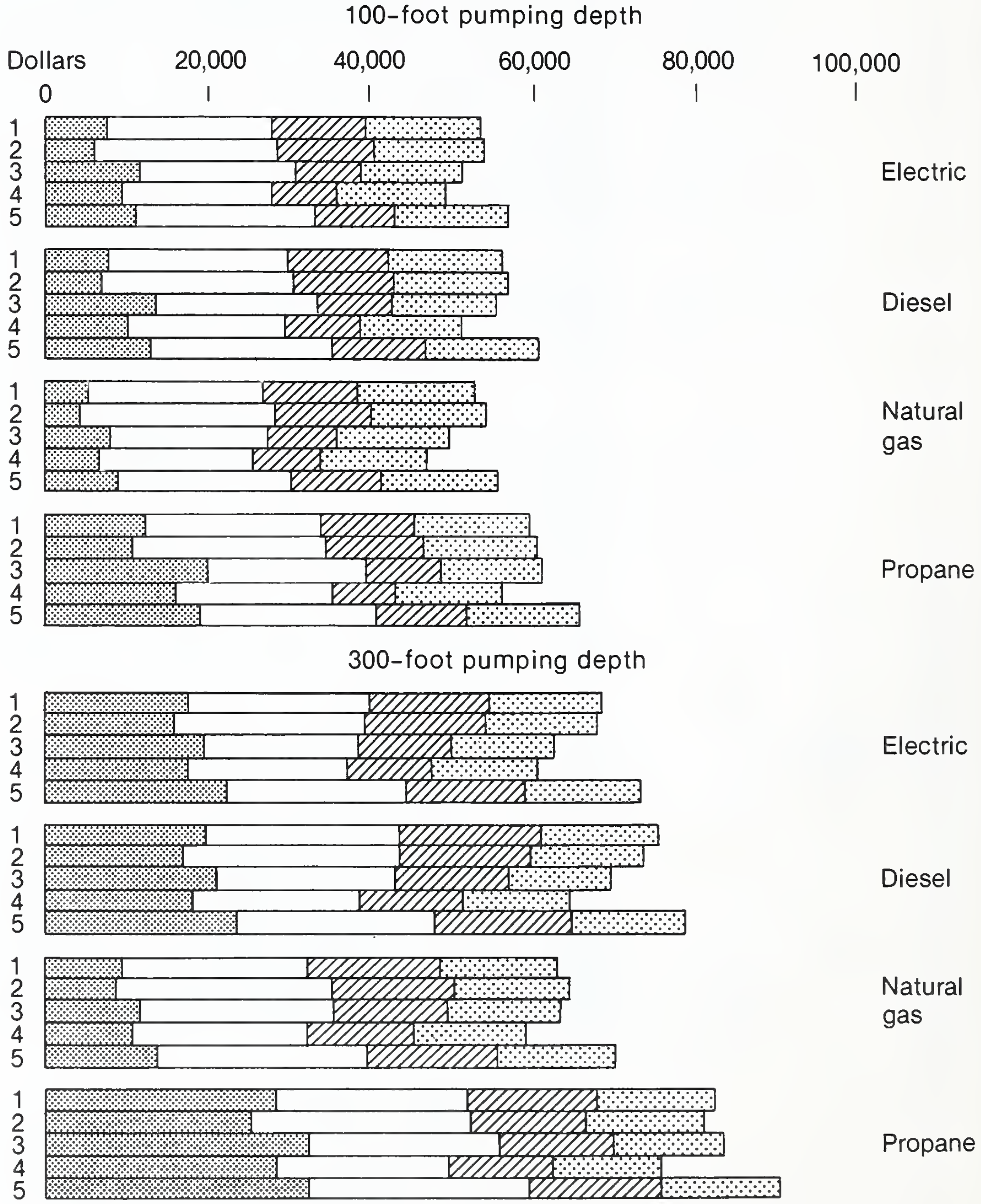
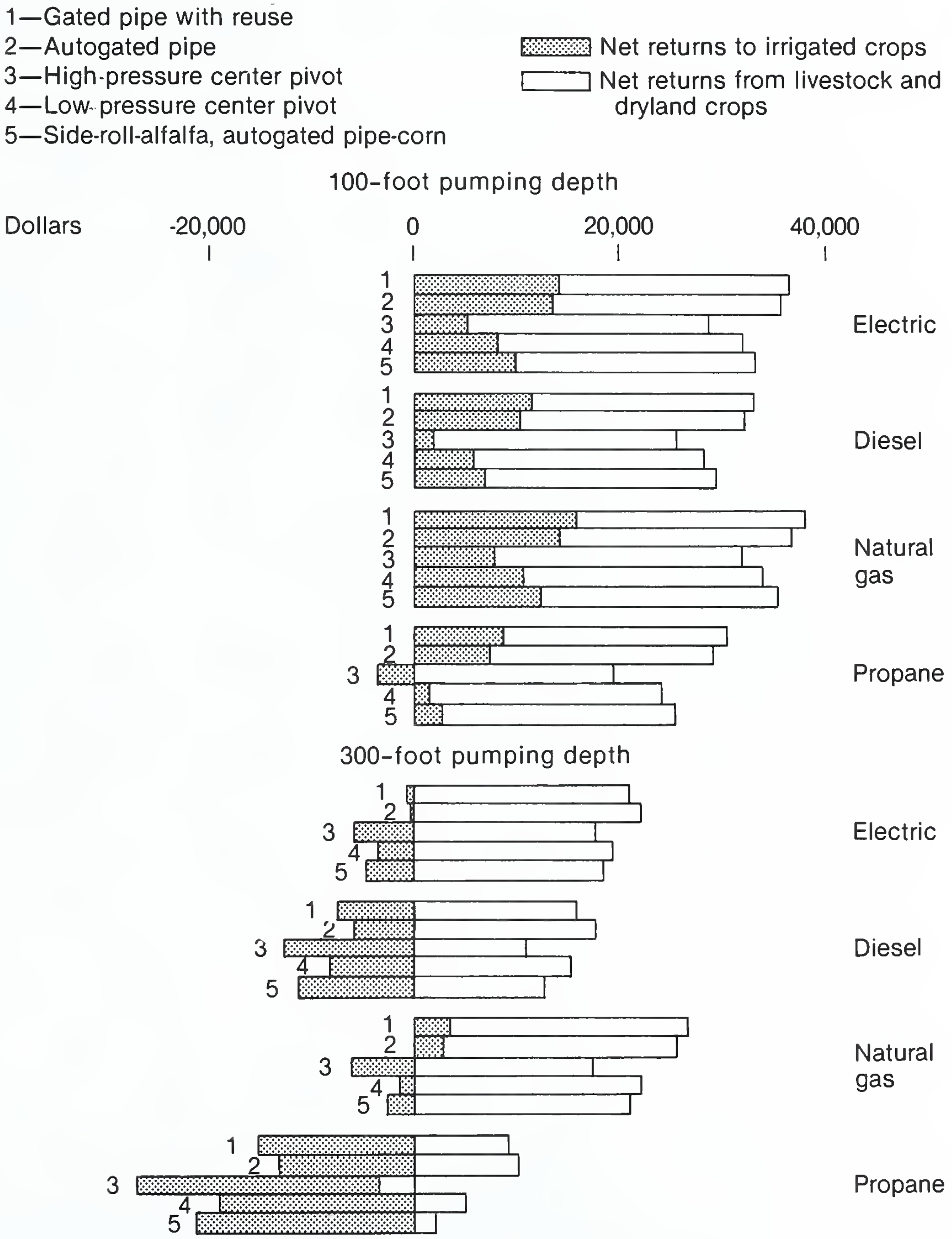


Figure 9

Returns to Land, Labor, Management, and Risk for Various Irrigation Systems on the Large Livestock Farm, Using Different Fuels, 100- and 300-Foot Pumping Depths, 1978



[1] The loss from irrigated crops was so extensive that it could not be offset by the returns from livestock and dryland crops, resulting in a total net loss of $7,175.

Table 12--Labor requirements of the large livestock farm, 1978

Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Hours											
Machinery labor for:												
Wheat-pivot farm	19	19	19	19	19	54	197	19	88	19	19	19
Wheat-nonpivot farm	19	19	19	19	19	54	197	19	88	19	19	19
Corn-pivot farm	8	8	8	26	184	47	36	8	8	8	155	8
Corn-nonpivot farm	10	10	10	30	218	56	43	10	10	10	184	10
Alfalfa-pivot farm	8	8	8	8	19	111	111	111	8	8	8	8
Alfalfa-nonpivot farm	10	10	10	10	22	131	131	131	10	10	10	10
Livestock labor	114	114	114	308	148	21	21	21	71	21	114	114
Irrigation labor for:												
Gated pipe with reuse--												
Corn	0	0	0	0	0	32	112	112	80	0	0	0
Alfalfa	0	0	0	0	48	80	144	120	64	0	0	0
Total	0	0	0	0	48	112	256	232	144	0	0	0
Autogated pipe--												
Corn	0	0	0	0	0	16	48	51	35	0	0	0
Alfalfa	0	0	0	0	24	35	64	51	27	0	0	0
Total	0	0	0	0	24	51	112	102	62	0	0	0
High pressure center pivot--												
Corn	0	0	0	0	0	9	27	28	20	0	0	0
Alfalfa	0	0	0	0	14	20	35	28	16	0	0	0
Total	0	0	0	0	14	29	62	56	36	0	0	0

Continued--

Table 12--Labor requirements of the large livestock farm, 1978--Continued

Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Hours						
Low-pressure center pivot--												
Corn	0	0	0	0	0	9	27	28	20	0	0	0
Alfalfa	0	0	0	0	14	20	35	28	16	0	0	0
Total	0	0	0	0	14	29	62	56	36	0	0	0
Side-roll--												
Alfalfa	0	0	0	0	48	80	144	120	64	0	0	0
Corn	0	0	0	0	0	16	48	51	35	0	0	0
Total	0	0	0	0	48	96	192	171	99	0	0	0
Summary--												
Gated pipe with reuse	153	153	153	367	455	374	648	413	323	60	327	153
Autogated pipe	153	153	153	367	431	313	504	283	241	60	327	153
High-pressure center pivot	149	149	149	361	384	262	427	215	211	56	296	149
Low-pressure center pivot	149	149	149	361	384	262	427	215	211	56	296	149
Side-roll	153	153	153	367	455	302	541	342	268	60	327	153

combination used for the other two irrigation distribution system examples would exceed the family labor available in July even if only 270 acres were irrigated. The farmer would, therefore, be forced to reduce the acreage irrigated to less than 270 acres, work additional hours, or find some seasonal labor to supplement the assumed family labor available. A farmer who cannot obtain a dependable supply of seasonal labor from year to year over the life of the irrigation system is likely to adopt systems which do not require labor beyond the amount of family labor available.

IRRIGATION SYSTEMS AND RISING ENERGY COSTS

Diesel fuel costs nearly doubled between 1978 and 1980 while other fuel prices rose 20 to 60 percent (table 6). The impact of these cost increases on returns to land, labor, management, and risk for the selected irrigation systems was greatest for the systems requiring high pressures and for farms with high pumping lifts. Many of the returns for farms with a 300-foot pumping lift became negative as prices increased from 1978 to 1980.

The input costs, commodity yields, and the current normalized commodity prices used to estimate the 1978 and 1980 costs and returns are presented in tables 4, 5, and 6. Investment and repair costs for machinery and equipment are based on the 1978 budgets.

Small Farm--100-Foot Pumping Lift

The surface water/ditch and siphon returns are nearly $24,000, $10,000 more than any of the diesel powered gated pipe systems (table 13). Only slight increases in cost accrue to the surface water/ditch and siphon system because the irrigation water is not pumped.

There is not a great deal of difference among the returns to the selected irrigation systems for the small farm. The greatest advantage in returns of one irrigation system over another is for ditch and siphon over autogated pipe with natural gas power, and that advantage is less than $2,000.

Intermediate Size Farm--100-Foot Pumping Lift

The relative ranking of the various irrigation systems does not change as energy costs rise because the most energy-efficient system of those examined for the intermediate size farm is autogated pipe (table 14). This system ranked the highest based on the 1978 prices. However, the difference in returns among fuels and systems increases. In 1978, autogated pipe with natural gas returned just over $5,000 more than big gun with natural gas. The returns for the same two systems differed by over $14,000 for propane in the same year. In 1980, the autogated pipe system yielded returns ranging from $11,000 to $25,000 more than big gun for natural gas and diesel, respectively.

Table 13--Variable costs and returns for alternative irrigation systems using selected fuels to power irrigation systems for 100-foot pumping lift wells on a small irrigated farm

Systems	1978				1980			
	Irrigation fuel & lube	Total variable cost	Returns to irrigated land 1/	Total returns 1/	Irrigation fuel & lube	Total variable cost	Returns to irrigated land 1/	Total returns 1/
	Dollars							
Natural gas:								
Gated pipe with reuse	1,832	26,971	22,084	22,084	2,750	30,527	18,528	18,528
Autogated pipe	1,752	27,870	21,403	21,403	2,349	31,105	18,169	18,169
Gated pipe without reuse	2,102	27,495	22,666	22,666	2,682	31,618	18,443	19,443
Ditch and siphon	1,907	27,491	23,176	23,176	2,433	30,702	19,965	19,965
Electric:								
Gated pipe with reuse	3,317	28,125	21,335	21,335	5,471	32,921	16,538	16,538
Autogated pipe	2,912	28,606	20,874	20,874	4,616	32,950	16,531	16,531
Gated pipe without reuse	3,718	28,640	21,932	21,932	5,896	33,466	17,106	17,106
Ditch and siphon	3,349	28,380	22,695	22,695	5,310	33,034	18,041	18,041
Diesel:								
Gated pipe with reuse	3,644	28,900	19,728	19,728	7,130	35,034	13,594	13,594
Autogated pipe	3,205	29,452	19,605	19,605	6,286	35,181	13,876	13,876
Gated pipe without reuse	4,127	29,677	20,050	20,050	8,166	36,372	13,355	13,355
Ditch and siphon	3,757	29,518	20,717	20,717	7,332	31,799	14,441	14,441
Propane:								
Gated pipe with reuse	5,320	30,459	18,596	18,596	6,541	34,318	14,737	14,737
Autogated pipe	4,712	30,830	18,443	18,443	5,761	34,517	14,757	14,757
Gated pipe without reuse	6,223	31,616	18,545	18,545	7,431	35,467	14,694	14,694
Ditch and siphon	5,645	31,229	19,438	19,438	6,741	35,010	15,657	15,657
Surface water-ditch and siphon	0	26.047	26,631	26,631	0	28,759	23,939	23,939

1/ Returns reflected are the returns to land, labor, management, and risk.

Table 14--Variable costs and returns for alternative irrigation systems using selected fuels to power irrigation systems for 100-foot pumping lift wells on an intermediate size farm

Systems	1978				1980			
	Irrigation fuel & lube	Total variable cost	Returns to irrigated land 1/	Total returns 1/	Irrigation fuel & lube	Total variable cost	Returns to irrigated land 1/	Total returns 1/
	Dollars							
Natural gas:								
Gated pipe with reuse	3,545	33,793	39,099	64,678	4,835	36,230	36,842	60,513
Autogated pipe	2,941	33,402	39,459	65,038	3,943	35,360	37,501	61,172
Big gun	11,793	42,223	31,024	59,521	15,866	47,263	25,984	49,655
High-pressure center pivot	5,757	35,419	33,152	58,731	7,873	38,615	29,956	53,719
Low-pressure center pivot	4,609	34,049	34,800	60,379	6,402	36,915	31,934	55,697
Electric:								
Gated pipe with reuse	5,754	35,408	38,074	63,653	9,136	40,717	32,765	56,436
Autogated pipe	4,886	34,706	38,564	64,143	7,744	38,531	34,740	58,411
Big gun	17,508	46,508	27,468	53,047	27,215	57,208	16,778	40,449
High-pressure center pivot	9,350	38,309	30,856	56,435	14,825	44,879	24,286	48,049
Low-pressure center pivot	7,290	36,174	33,123	58,702	11,559	41,286	28,011	51,774
Diesel:								
Gated pipe with reuse	6,323	36,962	35,639	61,218	12,522	44,048	28,554	52,225
Autogated pipe	5,383	36,055	36,373	61,952	10,547	42,195	30,234	53,905
Big gun	18,920	49,783	22,770	48,349	35,179	67,063	5,490	29,161
High-pressure center pivot	10,036	39,921	28,083	53,662	19,600	50,588	17,416	41,179
Low-pressure center pivot	7,822	37,395	31,068	56,647	15,226	45,890	22,573	46,336
Propane:								
Gated pipe with reuse	9,201	39,629	33,442	59,021	11,544	42,939	30,133	53,804
Autogated pipe	7,907	38,368	34,493	60,072	9,786	41,203	31,658	55,329
Big gun	26,331	56,760	16,487	46,023	32,629	64,026	9,221	32,892
High-pressure center pivot	14,863	44,525	24,046	49,625	18,682	49,424	19,147	42,910
Low-pressure center pivot	11,460	40,900	27,949	53,528	14,607	45,120	23,729	47,492

1/ Returns reflected are the returns to land, labor, management, and risk.

Large Livestock Farm--100-Foot Pumping Lift

There is also no change in the ranking of the various irrigation systems with the 1980 prices for the large livestock farm with the exception of the systems powered by diesel (table 15). The ranking of the systems when powered by diesel changes from gated pipe with reuse based on the 1978 prices to autogated pipe based on the 1980 prices.

The returns to irrigated land for the three sprinkler systems powered by diesel fuel or propane become negative as energy prices rise. Under these conditions the farmer cannot economically continue to irrigate for more than a few years since all fixed costs are not covered.

Farm Returns--300-Foot Pumping Lift

In all cases, autogated pipe is the system with the highest returns using 1978 and 1980 prices (table 16) for the small farm. The returns to diesel and propane powered systems become negative for the gated pipe without reuse and the ditch and siphon systems.

Again, autogated pipe remains the system with the highest returns for the intermediate size farm. Big gun and high-pressure center pivot sprinkler powered by diesel fuel and propane have negative returns (table 17).

Again, no changes occur in the ranking of various irrigation systems for the alternative fuels as prices rise (table 18) for the large livestock farm. The losses in returns to irrigated land for these systems on all three sample farms reflect a situation which must be resolved within the next 5 to 10 years or farmers will be forced to discontinue irrigation in these situations. The returns reflected in this report are to land, labor, management, and risk. Therefore, a negative return reflects a situation where the farmer is not even covering all the depreciation, tax, and insurance costs of farm equipment. In some of the situations, as in this 300-foot pumping lift example, the farmer is hardly covering out-of-pocket variable costs. If there is any other alternative market for the farmer's labor, the farmer will likely discontinue irrigation and switch to that alternative. Dryland farming or ranching may yield higher returns to labor and management than irrigated land and thus be a preferred alternative.

THE EFFECT OF FUTURE DIESEL FUEL PRICE INCREASES ON DIESEL POWERED IRRIGATION SYSTEMS

Higher fuel prices, especially for diesel fuel, are likely. The additional increase in costs due to a 50-cent increase in diesel fuel to $1.45 per gallon results in sharp decreases in returns for all three types of farms (table 19). The increase in costs for the 100-foot pumping lift situations for the small farm would not change any of the returns from positive to negative. The returns to irrigated land for the intermediate farm with a 100-foot pumping lift would remain positive for all

Table 15--Variable costs and returns for alternative irrigation systems using selected fuels to power irrigation systems for 100-foot pumping lift wells on a large livestock farm

Systems	1978				1980			
	Irrigation: fuel & lube	Total variable cost	Returns to irrigated land 1/	Total returns 1/	Irrigation: fuel & lube	Total variable cost	Returns to irrigated land 1/	Total returns 1/
	Dollars							
Natural gas:								
Gated pipe with reuse	4,279	25,109	14,939	37,561	5,831	28,418	11,631	33,498
Autogated pipe	3,635	26,648	13,226	35,848	4,874	29,644	10,230	32,097
Side-roll	7,803	28,960	11,599	34,221	9,840	33,010	7,645	29,512
High-pressure center pivot	7,116	25,868	7,864	30,416	9,724	29,981	3,752	25,578
Low-pressure center pivot	5,693	24,108	9,904	32,486	7,905	27,809	6,205	28,031
Electric:								
Gated pipe with reuse	6,955	27,000	13,666	36,288	11,029	32,853	7,813	29,680
Autogated pipe	6,039	27,397	12,637	35,259	9,576	32,704	7,332	29,199
Side-roll	11,349	31,705	9,575	32,197	17,235	39,286	1,991	23,858
High-pressure center pivot	11,556	29,379	4,954	27,536	18,323	37,684	-3,350	18,476
Low-pressure center pivot	9,012	26,690	7,776	30,358	14,287	33,478	988	22,814
Diesel:								
Gated pipe with reuse	7,632	28,839	10,557	33,179	14,920	37,931	1,465	23,332
Autogated pipe	6,648	29,583	9,811	32,433	13,076	37,806	1,588	23,455
Side-roll	12,108	33,837	6,327	28,949	21,124	44,293	-4,130	17,737
High-pressure center pivot	12,406	31,547	1,612	24,194	24,224	44,918	-11,757	10,069
Low-pressure center pivot	9,670	28,329	5,296	27,879	18,814	38,997	-5,371	16,455
Propane:								
Gated pipe with reuse	11,109	31,939	8,109	30,731	13,700	36,287	3,762	25,629
Autogated pipe	9,775	32,788	7,086	29,708	11,954	36,724	3,150	25,017
Side-roll	16,849	38,006	2,553	25,175	18,902	42,072	-1,417	20,450
High-pressure center pivot	18,369	37,121	-3,389	19,193	22,695	42,952	-9,219	12,607
Low-pressure center pivot	14,159	32,574	1,438	24,020	17,659	37,563	-3,549	18,277

1/ Returns reflected are the returns to land, labor, management, and risk.

Table 16--Variable costs and returns for alternative irrigation systems using selected fuels to power irrigation systems for 300-foot pumping lift wells on a small farm

Systems	1978				1980			
	Irrigation fuel & lube	Total variable cost	Returns to irrigated land 1/	Total returns 1/	Irrigation fuel & lube	Total variable cost	Returns to irrigated land 1/	Total returns 1/
	Dollars							
Natural gas:								
Gated pipe with reuse	4,707	30,499	15,769	15,769	6,171	34,614	11,654	11,654
Autogated pipe	4,161	30,372	17,181	17,181	5,424	34,283	13,270	13,270
Gated pipe without reuse	5,456	31,779	15,547	15,547	6,966	35,951	11,375	11,375
Ditch and siphon	5,585	32,252	15,599	15,599	7,131	36,506	11,345	11,345
Electric:								
Gated pipe with reuse	8,038	33,195	13,790	13,790	12,744	40,568	6,417	6,417
Autogated pipe	7,157	33,315	14,796	14,796	11,344	40,166	7,945	7,945
Gated pipe without reuse	9,634	35,041	13,014	13,014	15,265	43,356	4,699	4,699
Ditch and siphon	9,831	35,436	13,140	13,140	15,586	43,877	4,659	4,659
Diesel:								
Gated pipe with reuse	8,899	34,900	10,684	10,684	17,532	46,211	-627	-627
Autogated pipe	7,930	35,126	12,274	12,274	15,460	45,333	2,067	2,067
Gated pipe without reuse	10,708	37,305	9,325	9,325	21,191	50,482	-3,852	-3,852
Ditch and siphon	10,972	37,949	9,212	9,212	21,717	51,439	-4,278	-4,278
Propane:								
Gated pipe with reuse	13,251	39,043	7,225	7,225	16,021	44,464	1,804	1,804
Autogated pipe	11,841	38,052	9,501	9,501	14,281	43,140	4,413	4,413
Gated pipe without reuse	16,150	42,473	4,851	4,851	19,296	48,281	-955	-955
Ditch and siphon	16,535	43,202	4,649	4,649	19,756	49,131	-1,280	-1,280

1/ Returns reflected are the returns to land, labor, management, and risk.

Table 17--Variable costs and returns for alternative irrigation systems using selected fuels to power irrigation systems for 300-foot pumping lift wells on an intermediate size farm

Systems	1978				1980			
	Irrigation fuel & lube	Total variable cost	Returns to irrigated land 1/	Total returns 1/	Irrigation fuel & lube	Total variable cost	Returns to irrigated land 1/	Total returns 1/
	Dollars							
Natural gas:								
Gated pipe with reuse	8,150	39,922	29,946	55,525	10,711	43,482	26,387	50,058
Autogated pipe	6,986	38,756	31,059	56,638	9,101	41,856	27,959	51,630
Big gun	16,204	50,639	17,670	43,249	21,495	56,941	11,368	35,039
High-pressure center pivot	9,253	41,957	21,276	46,855	12,331	46,154	16,879	40,642
Low-pressure center pivot	7,989	39,414	25,391	50,970	10,716	43,241	21,564	45,327
Electric:								
Gated pipe with reuse	13,876	44,263	26,378	51,975	22,176	53,251	17,408	41,079
Autogated pipe	12,009	42,559	27,982	53,561	19,037	50,595	19,946	43,617
Big gun	25,365	55,159	16,281	41,860	39,677	70,513	927	24,598
High-pressure center pivot	15,390	45,087	21,273	46,852	24,400	55,242	11,118	34,881
Low-pressure center pivot	13,300	42,840	23,822	49,401	21,084	51,746	14,916	38,679
Diesel:								
Gated pipe with reuse	15,350	47,615	21,569	47,148	29,082	62,400	6,784	30,455
Autogated pipe	13,309	45,456	23,664	49,243	26,243	59,251	9,869	33,540
Big gun	27,190	59,805	9,338	34,917	51,553	85,228	-16,086	7,585
High-pressure center pivot	16,589	47,928	16,399	41,978	32,570	65,052	-725	23,038
Low-pressure center pivot	14,378	45,082	20,265	45,844	28,193	60,027	5,320	29,083
Propane:								
Gated pipe with reuse	22,830	54,602	15,266	40,845	27,814	60,585	9,284	32,955
Autogated pipe	19,881	51,651	18,164	47,743	24,070	56,825	12,990	36,661
Big gun	39,390	73,825	-5,516	20,063	48,220	83,666	-15,357	8,314
High-pressure center pivot	25,215	57,919	5,314	30,893	31,033	64,856	-1,823	21,940
Low-pressure center pivot	21,468	52,893	11,912	37,491	26,558	59,083	5,722	29,485

1/ Returns reflected are the returns to land, labor, management, and risk.

Table 18--Variable costs and returns for alternative irrigation systems using selected fuels to power irrigation systems for 300-foot pumping lift wells on a large livestock farm

Systems	1978				1980			
	Irrigation fuel & lube	Total variable cost	Returns to irrigated land 1/	Total returns 1/	Irrigation fuel & lube	Total variable cost	Returns to irrigated land 1/	Total returns 1/
	Dollars							
Natural gas:								
Gated pipe with reuse	9,837	32,468	3,330	25,952	12,929	37,383	1,589	20,278
Autogated pipe	8,631	34,413	2,565	25,187	11,252	38,862	-1,763	20,104
Side-roll	13,111	37,673	-2,135	20,487	16,261	42,488	-6,950	14,917
High-pressure center pivot	11,438	34,612	-6,269	16,313	15,241	40,009	-11,664	10,162
Low-pressure center pivot	9,874	31,190	-1,257	21,325	13,246	36,153	-6,220	15,606
Electric:								
Gated pipe with reuse	16,748	37,900	-982	21,640	26,555	49,591	-12,673	9,194
Autogated pipe	14,844	37,393	-105	22,517	23,535	47,944	-10,656	11,211
Side-roll	20,747	42,324	-4,851	17,771	32,134	55,307	-17,883	3,984
High-pressure center pivot	18,367	37,427	-5,928	16,654	30,163	50,867	-19,367	2,459
Low-pressure center pivot	16,439	35,206	-3,398	19,184	26,064	46,417	-14,609	7,217
Diesel:								
Gated pipe with reuse	18,535	41,893	-7,141	15,481	36,489	61,787	-27,036	-5,169
Autogated pipe	16,450	41,993	-5,728	16,894	32,440	59,904	-23,640	-1,773
Side-roll	22,443	46,347	-10,624	11,998	40,233	65,889	-30,167	-8,300
High-pressure center pivot	20,505	41,851	-12,404	10,178	40,255	63,247	-33,799	-11,973
Low-pressure center pivot	17,771	38,173	-7,696	14,886	34,851	56,866	-26,387	-4,561
Propane:								
Gated pipe with reuse	27,561	50,192	-14,394	8,228	33,361	57,815	-22,021	-154
Autogated pipe	24,565	50,347	-13,249	9,373	29,623	57,233	-23,134	1,737
Side-roll	32,562	57,124	-21,586	1,036	36,689	62,916	-27,378	-5,511
High-pressure center pivot	31,168	54,342	-25,999	-3,417	37,983	62,751	-34,406	-12,580
Low-pressure center pivot	26,534	47,850	-17,917	4,665	32,452	55,359	-25,426	-3,600

1/ Returns reflected are the returns to land, labor, management, and risk.

Table 19--Estimated irrigation fuel cost increases with a 50-cent per gallon increase in diesel fuel from 1980 prices to $1.45 per gallon 1/

Irrigation system	Increase in irrigation fuel cost, small farm	Increase in irrigation fuel cost, intermediate size farm	Increase in irrigation fuel cost, large livestock farm
		Dollars	
100-foot pumping lift:			
Gated pipe with reuse	2,985	5,206	6,193
Autogated pipe	2,688	4,506	5,570
Gated pipe without reuse	3,739	--	--
Ditch and siphon	3,399	--	--
High-pressure center pivot	--	9,875	10,315
Low-pressure center pivot	--	7,427	7,762
Big gun	--	13,813	--
Side-roll and autogated pipe	--	--	8,270
300-foot pumping lift:			
Gated pipe with reuse	7,788	13,383	16,154
Autogated pipe	7,002	11,751	14,526
Gated pipe without reuse	9,752	--	--
Ditch and siphon	9,894	--	--
High-pressure center pivot	--	17,136	17,873
Low-pressure center pivot	--	14,688	15,320
Big gun	--	21,982	--
Side-roll and autogated pipe	--	--	17,831

-- = System was not used on sample farm.

1/ Machinery fuel costs increased $924 for all systems used on the small farm. On the intermediate size farm, machinery fuel costs increased $2,562 for the surface irrigation systems, $2,537 for the center pivot sprinklers, and $2,562 for the big gun. The large livestock farm incurred machinery fuel cost increases of $2,211 for gated pipe with reuse, autogated pipe, and the side-roll/autogated pipe combination, and $1,965 for the center pivot systems.

systems except big gun. The increase in costs for irrigated crop enterprises for the large livestock farm, which already had negative returns in 1980 for the side-roll and center pivot systems, would only further increase the loss situation. The returns to irrigated land for the ranch for the autogated pipe and gated pipe with reuse would become negative.

The increase in costs for all three farms using diesel fuel to pump irrigation water with a 300-foot pumping lift would change most of the remaining positive returns to irrigated land to negative returns or increase the negative returns. The only exceptions would be autogated pipe and gated pipe with reuse on the intermediate size farm.

The returns to irrigated land for the large livestock farm with a 300-foot pumping lift are not high enough to offset the variable cost of production with this 50-cent increase in diesel fuel cost for any of the irrigation systems. The returns to irrigated land also fail to cover the variable costs of production for the big gun system with a 300-foot pumping lift on the intermediate size farm and the high pressure center pivot with a 100-foot pumping lift on the large livestock farm. Farmers, therefore, would not have any motivation to begin farming this irrigated land for irrigated crop production even though the irrigation system is installed unless they felt that the commodity prices would increase beyond those used in this paper. For example, the farmer may expect corn prices to increase by 50 cents per bushel above the $2.34 used in this paper. Such an increase in corn prices would result in an increase in returns of $3,720 for the small farm, $17,920 for the 320 acres of corn on the intermediate size farm if gated pipe or autogated pipe were used, $17,360 for the 310 acres of corn if big gun were used, and $16,445 if only 270 acres of corn were irrigated by center pivots. The large livestock farm would show a $7,440 increase in returns if surface irrigation was used on 160 acres of corn, or $6,278 if center pivot irrigation was used on 135 acres of corn.

This 50-cent increase in the price of corn more than offsets the 50-cent increase in the price of diesel fuel for the corn enterprise on all three farms with a 100-foot pumping lift. However, the increase in the price of corn falls short of offsetting the 50-cent fuel increase for the entire farm, in some cases for the 100-foot pumping lift and, in most cases, for the 300-foot pumping lift. The 50-cent increase in corn price barely offsets the 50-cent increase in diesel fuel cost for the gated pipe with reuse, autogated pipe, and low-pressure center pivot systems for the intermediate farm with a 300-foot pumping lift. However, it does not cover the additional cost for the high-pressure center pivot or the big gun systems for the intermediate size farm.

Thus far, the analysis has been limited to a comparison of the alternative irrigation systems under different irrigation situations with changing costs and commodity prices. The comparison should help irrigators select an irrigation system for their own situation. The data can also be used to help decide whether or not converting the irrigator's system from one type of fuel source to another or from one type of irrigation system to another is viable. However, the benefits of conversion can be better addressed with some modification of the budgets. The following sections will briefly discuss some of the factors to be evaluated when considering conversion to an alternative fuel source or to an alternative irrigation system.

POTENTIAL CONVERSION FROM DIESEL POWERED IRRIGATION TO ELECTRICITY OR PROPANE

The rapid rise in diesel fuel costs of the last 2 years has encouraged irrigators using diesel fuel to examine their conversion alternatives. The savings in energy costs by converting from diesel fuel to natural gas would be greater than conversion to either electricity or propane; however, few irrigators have the opportunity to convert to natural gas due to its limited availability. The limited availability of electric power also inhibits conversion from diesel power in some areas. Electric power availability will vary considerably with the individual irrigator's situation. Some electric power suppliers have additional capacity in both power generation and power distribution systems which can be used to meet the needs of irrigators. Other electric power suppliers have limitations on generating capacity which prevent them from increasing the number of irrigation wells serviced without increasing peak generating capacity. (Irrigation pumping in the summer months is a prime contributor to the peak load problem for electric power generating capacity requirements.)

Power suppliers are also limited by the capacity of the powerlines that service the area where diesel-to-electric conversion is desired. Costs of additional powerlines or upgrading of existing lines to greater capacities may be economically prohibitive. Even in situations where capacity exists or where it is feasible to increase line or generation capacities, there are only a limited number of irrigators who could convert in any year due to limitations on labor and other resources required to connect the additional irrigation wells.

Conversion from diesel fuel to propane is not subject to th same type of supply and distribution system capacities a natural gas and electric power conversions. However, propan is directly affected by market price adjustments. Thus, th advantage that propane now holds over diesel in terms of marke price may disappear in the future. The prices of natural ga and electricity are partially controlled by institution restraints which may slow their adjustments to the curre

energy market situation; however, in the long run, these energy sources should become more competitive.

Powerplant Conversion from Diesel to Electricity

Returns increased in all situations where irrigators converted diesel powered systems to electricity (table 20). The greatest gains came from the most energy-intensive situations, as expected. Irrigators with 300-foot pumping lifts had gains as high as $6,746 for the small farm employing the ditch and siphon method, $13,612 for the intermediate size farm using big gun systems, and $11,269 for the large livestock farm using high-pressure center pivot systems.

Return estimates are based on two assumptions: the diesel engine and gearhead have no salvage value, and electric power is available with no installation cost. The estimated increase in returns from the conversion to electric power from diesel is equal to the difference in returns between the two power sources less the ownership costs of the diesel motor and gearhead. The diesel motor ownership cost is the estimated annual amortized cost of the diesel powerplant which is being replaced, assuming that the diesel powerplant is replaced before it is fully depreciated. The variations in the diesel engine ownership cost for the different irrigation systems reflect the differences in the annual hours of use and the size of the diesel engine necessary to meet the needs of each irrigation system.

The machinery and equipment prices used in these budgets are based on 1978 costs. There is likely to be an increase in the cost of the electric powerplant over the 1978 price level and there is likely to be some installation cost incurred during this conversion process. However, there may also be some minimal salvage value which could be obtained from the diesel powerplant. One of the reasons for leaving out the electric powerplant installation costs is the variability of that cost from zero to thousands of dollars, as discussed earlier in the report. The net returns to each irrigation system with diesel power, with electric power, and with electric power including the diesel engine ownership costs are presented in appendix tables 25-27.

Powerplant Conversion from Diesel to Propane

Most producers showed increased returns when converting irrigation systems to propane from diesel. However, the increases were not nearly as great as those shown for the diesel to electric powerplant conversion. The greatest increase for any farm was only $1,705 for the gated pipe with reuse system with a 300-foot pumping lift on the large livestock farm (table 21). The sprinkler irrigation systems on the intermediate size and large livestock farms with the 300-foot pumping lift exhibited net losses as a result of the conversion from diesel to propane.

Table 20--Estimated changes in returns to land, labor, management, and risk as a result of converting from diesel to electric pumping plants, 1980 1/

Irrigation system	Change in returns, small farm 2/	Change in returns, intermediate size farm 2/	Change in returns, large livestock farm 2/
		Dollars	
100-foot pumping lift:			
Gated pipe with reuse	1,813	3,027	4,617
Autogated pipe	2,081	3,357	4,779
Gated pipe without reuse	2,598	--	--
Ditch and siphon	2,455	--	--
Big gun	--	9,087	--
Side-roll	--	--	4,419
High-pressure center pivot	--	5,161	6,730
Low-pressure center pivot	--	4,145	5,056
300-foot pumping lift:			
Gated pipe with reuse	4,879	8,355	11,053
Autogated pipe	4,776	7,875	11,141
Gated pipe without reuse	6,345	--	--
Ditch and siphon	6,746	--	--
Big gun	--	13,612	--
Side-roll	--	--	9,298
High-pressure center pivot	--	8,711	11,269
Low-pressure center pivot	--	7,396	9,559

-- = System not used on sample farm.

1/ Variable costs, including fuel, are based on 1980 estimates. Investment costs are based on 1978 machinery prices.

2/ Returns reflected are the returns to land, labor, management, and risk.

Table 21--Estimated changes in returns to land, labor, management, and risk as a result of converting from diesel to propane pumping plants, 1980 1/

Irrigation system	Change in returns, small farm 2/	Change in returns, intermediate size farm 2/	Change in returns, large livestock farm 2/
		Dollars	
100-foot pumping lift:			
Gated pipe with reuse	12	395	566
Autogated pipe	307	275	597
Gated pipe without reuse	186	--	--
Ditch and siphon	71	--	--
Big gun	--	1,530	--
Side-roll	--	--	1,011
High-pressure center pivot	--	22	861
Low-pressure center pivot	--	-137	519
300-foot pumping lift:			
Gated pipe with reuse	266	231	1,705
Autogated pipe	1,244	919	1,667
Gated pipe without reuse	691	--	--
Ditch and siphon	807	--	--
Big gun	--	-2,672	--
Side-roll	--	--	-197
High-pressure center pivot	--	-4,230	-3,770
Low-pressure center pivot	--	-1,798	-1,258

-- = System not used on sample farm.

1/ Variable costs, including fuel, are based on 1980 estimates. Investment costs are based on 1978 machinery prices.

2/ Returns reflected are the returns to land, labor, management, and risk.

CONVERSION OF SELECTED IRRIGATION DISTRIBUTION SYSTEMS

Besides converting to different energy sources, irrigation system conversion to a more energy-efficient system may increase returns. Four likely types of irrigation system conversions were selected for analysis. They are:

* Adding a reuse system to a gated pipe without reuse system.

* Converting to a gated pipe with reuse system from a ditch and siphon system.

* Converting to an autogated pipe with reuse system from a gated pipe with reuse system.

* Converting a center pivot from high to low pressure.

Conversion from a sprinkler system to a surface system was not considered since it is likely that existing sprinkler systems were selected for the soil type and land topography or due to the lack of available irrigation labor. The system conversions considered either reduced labor requirements or held them constant. The exclusion of other possible conversions in this discussion does not imply that they are not feasible or desirable for any particular irrigation situation.

Adding a Reuse System to a Gated Pipe Without Reuse

The conversion from gated pipe without reuse to gated pipe with reuse for the small farm increases returns for all energy sources for the 300-foot pumping lift and for all energy sources except electricity and natural gas for the 100-foot pumping lift (table 22). Fuel cost rises for the natural gas powered gated pipe with reuse system with a 100-foot pumping lift because recycling the runoff water from the reuse pit with an electrically powered reuse pump costs more than pumping the additional water from the well.

The change in fuel costs and returns was estimated by subtracting the fuel costs and the returns for the gated pipe with reuse system from those for the gated pipe without reuse system. This estimation procedure essentially assumes that no additional cost is incurred by adding the reuse system to an existing gated pipe without reuse system more than would have been encountered had the entire system been installed initially. Some understatement of costs is likely in this assumption; however, on an annual amortized basis it should be minimal.

Converting to a Gated Pipe With Reuse System from a Ditch and Siphon System

Conversion to the gated pipe with reuse system from a ditch and siphon system on the small farm reduced energy costs and increased returns for all fuel types for the 300-foot pumping lift; by contrast, returns decreased for all the fuel types for the 100-foot pumping lift (table 22). The conversion cost

Table 22--Estimated changes in fuel costs and returns to land, labor, management, and risk resulting from alternative irrigation system conversions on selected farms, 1980

System conversions	Feet of lift	Electric		Diesel		Natural gas		Propane	
		Fuel costs savings	Change in returns	Fuel costs savings	Change in returns	Fuel costs savings	Change in returns	Fuel costs savings	Change in returns
		Dollars							
Small farm:									
Gated pipe without reuse to gated pipe with reuse	100	425	-568	1,036	239	1/-68	-915	890	43
	300	2,521	1,718	3,659	2,598	795	279	3,275	2,759
Ditch and siphon to gated pipe with reuse	100	-161	-1,503	202	-847	1/-317	-1,437	200	-920
	300	2,842	1,758	4,185	3,651	960	309	3,735	3,084
Intermediate size farm:									
Gated pipe with reuse to autogated pipe	100	1,392	1,975	1,975	1,680	892	659	1,758	1,525
	300	3,139	2,538	2,839	3,085	1,610	1,518	3,744	3,706
High-pressure center pivot to low-pressure center pivot	100	3,266	3,725	4,374	5,157	1,471	1,978	3,783	4,290
	300	3,316	3,798	4,377	6,045	1,615	4,685	4,475	7,345
Large livestock farm:									
High-pressure center pivot to low-pressure center pivot	100	4,036	4,338	5,410	6,386	1,818	2,453	5,036	5,670
	300	4,099	4,758	5,404	7,412	1,995	5,444	5,531	8,980

1/ Fuel costs increased in these examples.

estimates for the ditch and siphon to gated pipe with reuse did not assume any salvage value for the ditch and siphon equipment. The ditch and siphon system equipment includes a ditcher, a ditch closer, and siphon tubes.

Converting from a Gated Pipe With Reuse to an Autogated Pipe System

Conversion to autogated pipe from gated pipe with reuse on the intermediate size farm with either 100-foot or 300-foot pump lift reduced fuel costs and increased returns for all fuel types (table 22). Additional costs may be incurred in the conversion from gated pipe with reuse to autogated pipe above those reflected in this analysis, but when the expenses are spread over the life of the system, it is likely that there would still be increases in returns.

Converting a Center Pivot from High to Low Pressure

Both the intermediate size farm and the large livestock farm had reduced fuel costs and increased returns when converting from high- to low-pressure center pivot (table 22). The cost and return estimates are made by subtracting the fuel costs and returns for the low-pressure center pivot sample from the high-pressure center pivot sample fuel costs and returns. In addition, the annual ownership costs for the low-pressure center pivot are increased by the amortized costs of a $4,000 conversion charge.

Conversion may require removal of one pumping stage and rebuilding of the pump. The pump adjustments are necessary to match the pump to the new pressure requirement. Conversion also requires replacing high-pressure sprinkler heads with low-pressure sprinkler heads and regulators to maintain proper distribution of water for a center pivot system on rolling land. Regulators are not needed on level land. The regulators add approximately $700 to the conversion cost. The $4,000 estimate is based on a sample conversion of an electrically powered high-pressure center pivot to a low-pressure center pivot with adjustments in the irrigation pump. (The estimate was obtained from a company which converts center pivot systems from high to low pressure.)

The cost of the conversion process varies with the particular irrigation situation, and additional variations are possible if the irrigation pump is powered by a diesel, natural gas, or propane engine. In some cases, an adjustment can be made in the gearhead allowing the engine to be adjusted to operate at a lower rpm (revolutions per minute) and still maintain the gallons per minute and pressure required to run the low pressure center pivot system. The adjustment of the gear ratio in the gearhead and the adjustments of the rpm's of the diesel, natural gas, or propane engines may result in some decrease in the efficiency of the engine. The alternative is to replace the present engine with a lower horsepower engine that is more closely matched to the needs of the low pressure center pivot.

The potential increase in returns is slightly overstated since the low pressure center pivot powerplant ownership costs are based on the engine used in the low pressure sample. The engine in the low pressure sample is usually a less costly smaller horsepower engine. Actual replacement of the electric motor and the diesel, natural gas, and propane engines and gearheads as part of the conversion would increase the conversion cost, assuming no salvage value for the replaced engine. Costs for the intermediate size farm would have been increased by approximately $600, $1,700, $1,150, and $1,150 for the electric, diesel, natural gas, and propane conversions, respectively, for the 100-foot pumping lift. The ownership costs for the 300-foot pumping lift for the electric, diesel, natural gas, and propane engines would have increased by $1,100, $3,150, $4,250, and $4,250, respectively. The ownership costs for the large livestock farm would be increased by approximately $550, $1,700, $1,150, and $1,150, for electricity, diesel, natural gas, and propane conversions, respectively, for a 100-foot pumping lift. For a 300-foot pumping lift, the ownership costs would increase by $1,100, $3,150, $4,200, and $4,200 for the electric, diesel, natural gas, and propane conversions, respectively. In all cases, the increase in returns as a result of the conversion is greater than the potential ownership cost increase. The natural gas powered conversion is the only sample where the potential increase in returns is nearly offset by the cost increase.

Some irrigators will likely attempt to convert a high-pressure center pivot powered by diesel engine to a low-pressure center pivot powered by an alternative fuel source, probably electricity. This type of conversion would take advantage of both the powerplant conversion cost savings and the energy cost savings due to less energy being required to maintain the low-pressure center pivot system. The irrigator converting a system, which is already electrically powered, may also be encouraged to replace the present electric motor with a smaller electric motor, not only to improve the operating efficiency, but also to reduce the annual startup charges of many electric power companies which are based on the rated horsepower of the electric motor. Thus, irrigators could reduce this annual cost by converting their systems to a smaller electric motor. The irrigator who is presently using electric power may also find that the replaced electric motor has a fairly high salvage value.

Conversion from high-pressure center pivot to low-pressure center pivot is not feasible in all cases due to soils and topography. Low-pressure systems tend to have larger droplet size which may result in increased runoff or soil compaction in certain soil and topography conditions.

CONCLUSIONS

The selection of the best irrigation system for a particular farm is dependent on many criteria such as soil type, lay of the land, crops grown, farm labor availability, pumping lift, investment cost, energy cost, and energy availability. Thus, no one system is best for all farms.

Autogated pipe is the most energy-efficient irrigation system of those examined for the three farms. As energy costs increased, it became the most desirable system in almost all comparisons; however, it is a relatively new technology adaptable only to surface irrigation.

Low-pressure center pivot is the most energy-efficient <u>sprinkler</u> irrigation system examined in this report. Higher energy prices increase the energy cost saving of this system relative to high-pressure center pivot. However, the higher application rates of the low-pressure center pivot may result in runoff and erosion on soils with low intake rates or on steep slopes.

The relative cost of irrigating with systems powered by natural gas was lowest followed in ascending order by electricity, diesel fuel, and propane, using 1978 energy prices. In 1980, increases in diesel fuel costs made it the most costly energy source.

Rising energy costs have and will change not only the system selected but the economic feasibility of irrigation with any system. Many of the sample irrigation situations presented in this report had negative returns to land, labor, management, and risk on the irrigated land. Considering that the returns must provide income to meet any mortgages on the land and provide family wages to cover living costs, these examples indicate that some irrigators are now being faced with returns so low that they may soon discontinue irrigation.

Some irrigators may find that converting the irrigated land back to dryland production, converting to a less energy-intensive system, or modifying an existing system to reduce energy needs may yield higher returns to their labor and investment. If the salvage value of the existing system is low, losses may be minimized by irrigating with the present system until it must be replaced. At that point, the irrigator would discontinue irrigation, assuming the economics of the situation had not changed. For example, the high-pressure center pivot on the 6,000-acre ranch with a 100-foot pumping lift using electric power had a loss of $3,350. The amortized cost of the irrigation system was $7,977. If the system had no salvage value, the irrigator's decision whether to irrigate or not would be based on a return of $4,627 to the irrigated land

compared with a $2,998 return to dryland wheat or a $972 return to dryland pasture. Although the $4,627 return would not justify replacement of the system, the irrigator in this situation may find that the best alternative is to continue irrigation until a major replacement investment is necessary.

Some irrigators may be able to reduce energy costs by converting to a less expensive energy source. At present, the examples discussed indicate that some irrigators may find conversion from diesel fuel to electricity or propane economically feasible. However, electricity is not always available for conversion. The diesel to propane conversions are not likely to be limited; however, the benefits may be only temporary since a small change in the relative price of diesel fuel and propane could negate any benefits.

Some irrigators may also benefit from converting their present systems to less energy-intensive systems. Converting a ditch and siphon system to gated pipe with reuse was found to be economical for a 300-foot pumping lift situation for all fuel types. Conversion of a gated pipe without reuse to an autogated pipe with reuse or just adding a reuse system was economically justified in all 300-foot pumping lift examples and for some 100-foot pumping lift situations. Finally, the sample conversions of a high-pressure center pivot to a low-pressure center pivot were economically justified for both 100-foot and 300-foot pumping lifts for all fuel types.

Labor requirements for the alternative irrigation systems became a limiting factor for the irrigation system selection process as farm size increased. The two larger farms had situations where a farmer might be encouraged to use a more capital- and/or energy-intensive system to bring the total farm labor requirements during peak months within the supply of labor available on the farm.

RELATED STUDIES

The impact of rising energy costs on irrigators has been examined by a number of different studies at the crop enterprise level and the State or area levels. The majority of these research studies relate to two geographic areas: (1) the Texas Trans Pecos and High Plains areas and the Oklahoma Panhandle, and (2) the areas of Nebraska, Colorado, Wyoming, and Kansas which have experienced a rapid development of center pivot irrigation. In 1975, Condra and Lacewell used crop enterprise budgets and linear programing to examine the demand for water under alternative crop and input prices (6). Irrigated agriculture in the High Plains was found to be vulnerable to low crop prices and rising natural gas costs. Further studies at Texas A & M examined the impacts of energy cost increases and energy shortages (15, 16, 29). These studies also found that rising energy costs would force

adjustments in irrigation practices, the crops irrigated, and the acres irrigated with some irrigators being forced to quit pumping. A study of the Oklahoma Panhandle found rising energy costs to have impacts similar to those in the above Texas studies (17).

Studies at the University of Nebraska and Colorado State University also examined the impacts of rising energy costs and what adjustments irrigators can make. Two University of Nebraska studies found that there is considerable variability in the impact of rising energy costs on irrigators with different irrigation systems and with different pumping lifts (13, 14). The studies also indicated that higher energy prices will encourage conservation and discourage additional irrigation development.

Skold identified a number of alternative conservation measures which could reduce energy usage (19). Selecting a more energy-efficient system was one of the alternatives. Gated pipe and center pivot systems were compared in a study by Sharp, Skold, and Lewis. This study found gated pipe preferable in many cases but also determined that many factors, other than energy efficiency, must be evaluated when selecting an irrigation system (18).

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Appendix table 1--Costs and returns for small farm, electric irrigation systems, 100-foot pumping depth and ditch and furrow irrigation system using surface water, 1978

Costs and returns	Gated pipe with reuse	Gated pipe without reuse	Auto-gated pipe	Surface ditch pumped water	Surface ditch surface water
	Dollars				
Irrigation fuel and lube	3,317	3,718	2,912	33,219	0
Irrigation repair	522	610	1,414	614	341
Interest on operating capital	1,052	1,078	1,046	1,096	1,089
Other variable costs	23,234	23,234	23,234	23,321	24,638
Total variable costs	28,125	28,640	28,606	28,380	26,068
Irrigation equipment ownership costs	5,555	4,442	5,533	3,738	2,115
Other ownership costs	10,186	10,186	10,186	10,387	10,387
Total cost	43,866	43,268	44,325	42,505	38,570
Net return to land, labor, management, and risk	21,335	21,932	20,874	22,695	26,630

Appendix table 2--Costs and returns for small farm, diesel irrigation systems, 100-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Gated pipe without reuse	Auto-gated pipe	Surface ditch pumped water
	Dollars			
Irrigation fuel and lube	3,644	4,127	3,205	3,757
Irrigation repair	945	1,206	1,942	1,308
Interest on operating capital	1,077	1,110	1,071	1,132
Other variable costs	23,234	23,234	23,234	23,321
Total variable costs	28,900	29,677	29,452	29,518
Irrigation equipment ownership costs	6,386	5,287	5,957	4,578
Other ownership costs	10,186	10,186	10,186	10,387
Total cost	45,472	45,150	45,595	44,483
Net return to land, labor, management, and risk	19,728	20,050	19,605	20,717

Appendix table 3--Costs and returns for small farm, natural gas irrigation systems, 100-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Gated pipe without reuse	Auto-gated pipe	Surface ditch pumped water
	Dollars			
Irrigation fuel and lube	1,832	2,102	1,752	1,907
Irrigation repair	877	1,110	1,857	1,197
Interest on operating capital	1,028	1,049	1,027	1,066
Other variable costs	23,234	23,234	23,234	23,321
Total variable costs	26,971	27,495	27,870	27,491
Irrigation equipment ownership costs	5,959	4,853	5,740	4,146
Other ownership costs	10,186	10,186	10,186	10,387
Total cost	43,116	42,534	43,796	42,024
Net return to land, labor, management, and risk	22,084	22,666	21,403	23,176

Appendix table 4--Costs and returns for small farm, propane irrigation systems, 100-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Gated pipe without reuse	Auto-gated pipe	Surface ditch pumped water
	Dollars			
Irrigation fuel and lube	5,320	6,223	4,712	5,645
Irrigation repair	877	1,110	1,857	1,197
Interest on operating capital	1,028	1,049	1,027	1,066
Other variable costs	23,234	23,234	23,234	23,321
Total variable costs	30,459	31,616	30,830	31,229
Irrigation equipment ownership costs	5,959	4,853	5,740	4,146
Other ownership costs	10,186	10,186	10,186	10,387
Total cost	46,604	46,665	46,756	45,492
Net return to land, labor, management, and risk	18,596	18,545	18,443	19,438

Appendix table 5--Costs and returns for small farm, electric irrigation systems, 300-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Gated pipe without reuse	Auto-gated pipe	Surface ditch pumped water
	Dollars			
Irrigation fuel and lube	8,038	9,634	7,159	9,831
Irrigation repair	764	965	1,778	1,037
Interest on operating capital	1,159	1,213	1,146	1,247
Other variable costs	23,234	23,234	23,234	23,321
Total variable costs	33,195	35,041	33,315	35,436
Irrigation equipment ownership costs	8,029	6,959	6,903	6,237
Other ownership costs	10,186	10,186	10,186	10,387
Total cost	51,410	52,186	50,404	52,060
Net return to land, labor, management, and risk	13,790	13,014	14,796	13,140

Appendix table 6--Costs and returns for small farm, diesel irrigation systems, 300-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Gated pipe without reuse	Auto-gated pipe	Surface ditch pumped water
	Dollars			
Irrigation fuel and lube	8,899	10,708	7,930	10,972
Irrigation repair	1,550	2,076	2,760	2,328
Interest on operating capital	1,217	1,287	1,202	1,328
Other variable costs	23,234	23,234	23,234	23,321
Total variable costs	34,900	37,305	35,126	37,949
Irrigation equipment ownership costs	9,430	8,384	7,614	7,652
Other ownership costs	10,186	10,186	10,186	10,387
Total cost	54,516	55,875	52,926	55,988
Net return to land, labor, management, and risk	10,684	9,325	12,274	9,212

Appendix table 7--Costs and returns for small farm, natural gas irrigation systems, 300-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Gated pipe without reuse	Auto-gated pipe	Surface ditch pumped water
	Dollars			
Irrigation fuel and lube	4,707	5,456	4,161	5,585
Irrigation repair	1,461	1,951	1,897	2,181
Interest on operating capital	1,097	1,138	1,080	1,165
Other variable costs	23,234	23,234	23,234	23,321
Total variable costs	30,499	31,779	30,372	32,252
Irrigation equipment ownership costs	8,746	7,688	7,461	6,962
Other ownership costs	10,186	10.186	10,186	10.387
Total cost	49,431	49,653	48,019	49,601
Net return to land, labor, management, and risk	15,769	15,547	17,181	15,599

Appendix table 8--Costs and returns for small farm, porpane irrigation systems, 300-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Gated pipe without reuse	Auto-gated pipe	Surface ditch pumped water
	Dollars			
Irrigation fuel and lube	13,251	16,150	11,841	16,535
Irrigation repair	1,461	1,951	1,897	2,181
Interest on operating capital	1,097	1,138	1,080	1,165
Other variable costs	23,234	23,234	23,234	23,321
Total variable costs	39,043	42,473	38,052	43,202
Irrigation equipment ownership costs	8,746	7,688	7,461	6,962
Other ownership costs	10,186	10,186	10,186	10,186
Total cost	57,975	60,349	55,699	60,551
Net return to land, labor, management, and risk	7,225	4,851	9,501	4,649

Appendix table 9--Costs and returns for intermediate size farm, electric irrigation systems, 100-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	Big gun	High-pressure center pivot	Low-pressure center pivot
	Dollars				
Irrigation fuel and lube	5,754	4,886	17,508	9,350	7,290
Irrigation repair	1,989	2,122	1,922	1,609	1,585
Interest on operating capital	1,293	1,244	1,466	1,303	1,252
Other variable costs	26,454	26,454	25,612	26,047	26,047
Total variable costs	35,408	34,706	46,508	38,309	36,174
Irrigation equipment ownership costs	11,155	11,366	7,970	7,903	7,771
Other ownership costs	8,829	8,829	8,599	9,495	9,495
Total cost	55,392	54,901	63,077	55,707	53,440
Net return to irrigated land, labor, management and risk	38,074	38,564	27,468	30,856	33,123
Net return including dryland crops	63,653	64,143	53,047	56,435	58,702

Appendix table 10--Costs and returns for intermediate size farm, diesel irrigation systems, 100-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	Big gun	High-pressure center pivot	Low-pressure center pivot
	Dollars				
Irrigation fuel and lube	6,323	5,383	18,920	10,036	7,822
Irrigation repair	2,838	2,925	3,664	2,508	2,255
Interest on operating capital	1,347	1,293	1,587	1,330	1,271
Other variable costs	26,454	26,454	25,612	26,047	26,047
Total variable costs	36,962	36,055	49,783	39,921	37,395
Irrigation equipment ownership cists	12,035	12,208	9,393	9,064	8,605
Other ownership costs	8,829	8,829	8,599	9,495	9,495
Total cost	57,826	57,092	67,775	58,480	55,495
Net return to irrigated land, labor, management, and risk	35,639	36,373	22,770	28,083	31,068
Net return including dryland crops	61,218	61,952	48,349	53,662	56,647

Appendix table 11--Costs and returns for intermediate size farm, natural gas irrigation systems, 100-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	Big gun	High-pressure center pivot	Low-pressure center pivot
	Dollars				
Irrigation fuel and lube	3,545	2,941	11,793	5,757	4,609
Irrigation repair	2,723	2,797	3,463	2,384	2,195
Interest on operating capital	1,251	1,210	1,355	1,231	1,198
Other variable costs	26,454	26,454	25,612	26,047	26,047
Total variable costs	33,793	33,402	42,223	35,419	34,049
Irrigation equipment ownership costs	11,565	11,776	8,699	8,497	8,219
Other ownership costs	8,829	8,829	8,599	9,495	9,495
Total cost	54,367	54,007	59,521	53,411	51,763
Net return to irrigated land, labor, management, and risk	39,099	39,459	31,024	33,152	34,800
Net return including dryland crops	64,678	65,038	56,603	58,731	60,379

Appendix table 12--Costs and returns for intermediate size farm, propane irrigation systems, 100-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	Big gun	High-pressure center pivot	Low-pressure center pivot
	Dollars				
Irrigation fuel and lube	9,201	7,907	26,331	14,863	11,460
Irrigation repair	2,723	2,797	3,463	2,384	2,195
Interest on operating capital	1,251	1,210	1,355	1,231	1,198
Other variable costs	26,454	26,454	25,612	26,047	26,047
Total variable costs	39,629	38,368	56,760	44,525	40,900
Irrigation equipment ownership costs	11,565	11,776	8,699	8,497	8,219
Other ownership costs	8,829	8,829	8,599	9,495	9,495
Total cost	60,023	58,973	74,058	62,517	58,614
Net return to irrigated land, labor, management, and risk	33,442	34,493	16,487	24,046	27,949
Net return including dryland crops	59,021	60,072	46,023	49,625	53,528

Appendix table 13--Costs and returns for intermediate size farm, electric irrigation systems, 300-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	Big gun	High-pressure center pivot	Low-pressure center pivot
	Dollars				
Irrigation fuel and lube	13,876	12,009	25,365	15,390	13,300
Irrigation repair	2,419	2,656	2,502	2,133	2,079
Interest on operating capital	1,514	1,440	1,680	1,517	1,414
Other variable costs	26,454	26,464	25,612	26,047	26,047
Total variable costs	44,263	42,559	55,159	45,087	42,840
Irrigation equipment ownership costs	13,978	14,096	10,506	10,708	10,406
Other ownership costs	8,829	8,829	8,599	9,495	9,495
Total cost	67,070	65,484	74,264	65,290	62,741
Net return to irrigated land, labor, management, and risk	26,378	27,982	16,281	21,273	23,822
Net return including dryland crops	51,975	53,561	41,860	46,852	49,401

Appendix table 14--Costs and returns for intermediate size farm, diesel irrigation systems, 300-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	Big gun	High-pressure center pivot	Low-pressure center pivot
	Dollars				
Irrigation fuel and lube	15,350	13,309	27,190	16,589	14,378
Irrigation repair	4,176	4,147	5,242	3,775	3,205
Interest on operating capital	1,635	1,546	1,761	1,517	1,452
Other variable costs	26,454	26 454	25,612	26,047	26,047
Total variable costs	47,615	45,456	59,805	47,928	45,082
Irrigation equipment ownership costs	15,453	15,517	12,803	12,741	11,721
Other ownership costs	8,829	8,829	8,599	9,495	9,495
Total cost	71,897	69,802	82,897	70,164	66,298
Net return to irrigated land, labor, management, and risk	21,569	23,664	9,338	16,399	20,265
Net return including dryland crops	47,148	49,243	34,917	41,978	45,844

Appendix table 15--Costs and returns for intermediate size farm, natural gas irrigation systems, 300-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	Big gun	High-pressure center pivot	Low-pressure center pivot
	Dollars				
Irrigation fuel and lube	8,150	6,986	16,204	9,253	7,989
Irrigation repair	3,923	3,978	7,276	5,254	4,058
Interest on operating capital	1,395	1,338	1,547	1,403	1,320
Other variable costs	26,454	26,454	25,612	26,047	26,047
Total variable costs	39,922	38,756	50,639	41,957	39,414
Irrigation equipment ownership costs	14,768	14,822	13,637	13,835	12,263
Other ownership costs	8.829	8,829	8,599	9,495	9,495
Total cost	63,519	62,407	72,875	65,287	61,172
Net return to irrigated land, labor, management, and risk	29,946	31,059	17,670	21,276	25,391
Net return including dryland crops	55,525	56,638	43,249	46,855	50,970

Appendix table 16--Costs and returns for intermediate size farm, propane irrigation systems, 300-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	Big gun	High-pressure center pivot	Low-pressure center pivot
	Dollars				
Irrigation fuel and lube	22,830	19,881	39,390	25,215	21,468
Irrigation repair	3,923	3,978	7,276	5,254	4,058
Interest on operating capital	1,395	1,338	1,547	1,403	1,320
Other variable costs	26,454	26,454	25,612	26,047	26,047
Total variable costs	54,602	51,651	73,825	57,919	52,893
Irrigation equipment ownership costs	14,768	14,822	13,637	13,835	12,263
Other ownership costs	8,829	8,829	8,599	9,495	9,495
Total cost	78,199	75,302	96,061	81,249	74,651
Net return to irrigated land, labor, management, and risk	15,266	18,164	- 5,516	5,314	11,912
Net return including dryland crops	40,845	47,743	20,063	30,893	37,491

Appendix table 17--Costs and returns for large livestock farm, electric irrigation systems, 100-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	High-pressure center pivot	Low-pressure center pivot	Side-roll-alfalfa/autogated pipe-corn
			Dollars		
Irrigation fuel and lube	6,955	6,039	11,556	9,012	11,349
Irrigation repair	1,742	3,110	2,337	2,303	2,048
Interest on operating capital	1,389	1,334	1,315	1,204	1,394
Other variable costs	16,914	16,914	14,171	14,171	16,914
Total variable costs	27,000	27,397	29,379	26,690	31,705
Irrigation equipment ownership costs	10,704	11,334	7,977	7,845	10,093
Other ownership costs	13,958	13,958	12,810	12,810	13,958
Total cost	51,662	52,789	50,166	47,345	55,756
Net return to irrigated land, labor, management, and risk	13,666	12,637	4,954	7,776	9,575
Net return including livestock and dryland crops	36,288	35,259	27,536	30,358	32,197

Appendix table 18--Costs and returns for large livestock farm, diesel irrigation systems, 100-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	High-pressure center pivot	Low-pressure center pivot	Side-roll-alfalfa/autogated pipe-corn
			Dollars		
Irrigation fuel and lube	7,632	6,648	12,406	9,670	12,108
Irrigation repair	2,790	4,563	3,589	3,234	3,271
Interest on operating capital	1,503	1,458	1,381	1,253	1,544
Other variable costs	16,914	16,914	14,171	14,171	16,914
Total variable costs	28,839	29,583	31,547	49,824	59,002
Irrigation equipment ownership costs	11,974	11,976	9,150	8,685	11,207
Other ownership costs	13,958	13,958	12,810	12,810	13,958
Total cost	54,771	55,517	53,507	49,824	59,002
Net return to irrigated land, labor, management, and risk	10,557	9,811	1,612	5,296	6,327
Net return including livestock and dryland crops	33,179	32,433	24,194	27,878	28,949

Appendix table 19--Costs and returns for large livestock farm, natural gas irrigation systems, 100-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	High-pressure center pivot	Low-pressure center pivot	Side-roll-alfalfa/ autogated pipe-corn
	Dollars				
Irrigation fuel and lube	4,279	3,635	7,116	5,693	7,803
Irrigation repair	2,622	4,808	3,416	3,152	3,003
Interest on operating capital	1,294	1,291	1,165	1,092	1,240
Other variable costs	16,914	16,914	14,171	14,171	16,914
Total variable costs	25,109	26,648	25,868	24,108	28,960
Irrigation equipment ownership costs	11,321	11,496	8,578	8,297	10,715
Other ownership costs	13,958	13,958	12,810	12,810	13,958
Total cost	50,388	52,102	47,256	45,215	53,663
Net return to irrigated land, labor, management, and risk	14,939	13,226	7,864	9,904	11,599
Net return including livestock and dryland crops	37,561	35,848	30,416	32,486	34,221

Appendix table 20- Costs and returns for large livstock farm, propane irrigation systems, 100-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	High-pressure center pivot	Low-pressure center pivot	Side-roll-alfalfa/ autogated pipe-corn
	Dollars				
Irrigation fuel and lube	11,109	10,068	18,369	14,159	16,849
Irrigation repair	2,622	4,808	3,416	3,152	3,003
Interest on operating capital	1,294	1,291	1,165	1,092	1,240
Other variable costs	16,914	15,914	14,171	14,171	16,914
Total variable costs	31,939	33,081	37,121	32,574	38,006
Irrigation equipment ownership costs	11,321	11,496	8,578	8,297	10,715
Other ownership costs	13,958	13,958	12,810	12,810	13,958
Total cost	57,218	58,535	58,509	53,681	62,679
Net return to irrigated land, labor, management, and risk	8,109	6,793	- 3,389	1,438	2,553
Net return including livestock and dryland crops	30,731	29,415	19,193	24,020	25,175

Appendix table 21--Costs and returns for large livestock farm, electric irrigation systems, 300-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	High-pressure center pivot	Low-pressure center pivot	Side-roll-alfalfa/ autogated pipe-corn
	Dollars				
Irrigation fuel and lube	16,748	14,844	18,367	16,439	20,747
Irrigation repair	2,382	3,875	3,102	3,032	2,729
Interest on operating capital	1,856	1,760	1,787	1,564	1,934
Other variable costs	16,914	16,914	14,171	14,171	16,914
Total variable costs	37,900	37,393	37,427	35,206	42,324
Irrigation equipment ownership costs	14,452	14,082	10,811	10,503	13,896
Other ownership costs	13,958	13,958	12,810	12,810	13,958
Total cost	67,824	66,795	65,256	59,354	71,393
Net return to irrigated land, labor, management, and risk	- 982	- 105	- 5,928	- 3,398	- 4,851
Net return including livestock and dryland crops	21,640	22,517	16,654	19,184	17,771

Appendix table 22--Costs and returns for large livestock farm, diesel irrigation systems, 300-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	High-pressure center pivot	Low-pressure center pivot	Side-roll-alfalfa/ autogated pipe-corn
	Dollars				
Irrigation fuel and lube	18,535	16,450	20,505	17,771	22,443
Irrigation repair	4,330	6,600	5,378	4,582	4,911
Interest on operating capital	2,114	2,029	1,797	1,649	2,079
Other variable costs	16,914	16,914	14,171	14,171	16,914
Total variable costs	41,893	41,993	41,851	38,173	46,347
Irrigation equipment ownership costs	16,619	15,106	12,863	11,832	15,648
Other ownership costs	13,958	13,958	12,810	12,810	13,958
Total cost	76,348	74,543	67,524	62,815	77,441
Net return to irrigated land, labor, management, and risk	- 7,141	- 5,728	-12,404	-7,696	-10,624
Net return including livestock and dryland crops	15,481	16,894	10,178	14,886	11,998

Appendix table 23--Costs and returns for large livestock farm, natural gas irrigation systems, 300-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	High-pressure center pivot	Low-pressure center pivot	Side-roll-alfalfa/ autogated pipe-corn
	Dollars				
Irrigation fuel and lube	9,837	8,631	11,438	9,874	13,111
Irrigation repair	4,115	7,257	7,446	5,774	5,963
Interest on operating capital	1,602	1,611	1,557	1,371	1,685
Other variable costs	16,914	16,914	14,171	14,171	16,914
Total variable costs	32,468	34,413	34,612	31,190	37,673
Irrigation equipment ownership costs	15,576	14,271	13,966	12,378	15,832
Other ownership costs	13,958	13,958	12,810	12,810	13,958
Total cost	62,672	63,244	62,659	56,378	67,720
Net return to irrigated land, labor, management, and risk	3,330	2,565	- 6,269	-1,257	- 2,135
Net return including livestock and dryland crops	25,952	25,187	16,313	21,325	20,487

Appendix table 24--Costs and returns for large livestock farm, propane irrigation systems, 300-foot pumping depth, 1978

Costs and returns	Gated pipe with reuse	Autogated pipe	High-pressure center pivot	Low-pressure center pivot	Side-roll-alfalfa/ autogated pipe-corn
	Dollars				
Irrigation fuel and lube	27,561	24,565	31,168	26,534	32,562
Irrigation repair	4,115	7,257	7,446	5,774	5,963
Interest on operating capital	1,602	1,611	1,557	1,371	1,685
Other variable costs	16,914	16,914	14,171	14,171	16,914
Total variable costs	50,192	50,347	54,342	47,850	57,124
Irrigation equipment ownership costs	15,576	14,271	13,966	12,378	15,832
Other ownership costs	13,958	13,958	12,810	12,810	13,958
Total cost	81,708	80,357	84,876	73,038	87,675
Net return to irrigated land, labor, management, and risk	-14,394	-13,249	-25,999	-17,917	-21,586
Net return including livestock and dryland crops	8,228	9,373	- 3,417	4,665	1,036

Appendix table 25--Estimated changes in returns to land, labor, management, and risk in converting from diesel to electric pumping plants on a small farm 1/

Irrigation system	Returns with diesel power	Returns with electric power	Diesel motor ownership cost	Returns with electric power/ diesel engine ownership cost	Change in returns
			Dollars		
100-foot pumping lift:					
Gated pipe with reuse	13,594	16,538	1,131	15,407	1,813
Autogated pipe	13,876	16,531	574	15,957	2,081
Gated pipe without reuse	13,355	17,106	1,153	15,953	2,598
Ditch and siphon	14,441	18,041	1,145	16,896	2,455
300-foot pumping lift:					
Gated pipe with reuse	-627	6,417	2,165	4,252	4,879
Autogated pipe	-2,067	7,945	1,102	6,843	4,776
Gated pipe without reuse	-3,852	4,699	2,206	2,493	6,345
Ditch and siphon	-4,278	4,659	2,191	2,468	6,746

1/ Variable costs, including fuel, are based on 1980 estimates. Investment costs are based on 1978 machinery prices.

Appendix table 26--Estimated changes in returns to land, labor, management, and risk in converting from diesel to electric pumping plants on an intermediate size farm 1/

Irrigation system	Returns with diesel power	Returns with electric power	Diesel motor ownership cost	Returns with electric power/ diesel engine ownership cost	Change in returns
			Dollars		
100-foot pumping lift:					
Gated pipe with reuse	52,225	56,436	1,184	55,252	3,027
Autogated pipe	53,905	58,411	1,149	57,262	3,357
Big gun	29,161	40,449	2,201	38,248	9,087
High-pressure center pivot	41,179	48,049	1,709	46,340	5,161
Low-pressure center pivot	46,336	51,774	1,293	50,481	4,145
300-foot pumping lift:					
Gated pipe with reuse	30,455	41,079	2,269	38,810	8,355
Autogated pipe	33,540	43,617	2,202	41,415	7,875
Big gun	7,585	24,598	3,401	21,197	13,612
High-pressure center pivot	23,038	34,881	3,132	31,749	8,711
Low-pressure center pivot	29,083	38,679	2,200	36,479	7,396

1/ Variable costs, including fuel, are based on 1980 estimates. Investment costs are based on 1978 machinery prices.

Appendix table 27--Estimated changes in returns to land, labor, management, and risk in converting from diesel to electric pumping plants on a large livestock farm 1/

Irrigation system	Returns with diesel power	Returns with electric power	Diesel motor ownership cost	Returns with electric power/ diesel engine ownership cost	Change in returns
	Dollars				
100-foot pumping lift:					
Gated pipe with reuse	23,332	29,680	1,731	27,949	4,617
Autogated pipe	23,455	29,199	965	28,234	4,779
Side-roll	17,737	23,858	1,702	22,156	4,419
High-pressure center pivot	10,069	18,476	1,677	16,799	6,730
Low-pressure center pivot	16,455	22,814	1,303	21,511	5,056
300-foot pumping lift:					
Gated pipe with reuse	-5,169	9,194	3,310	5,884	11,053
Autogated pipe	-1,773	11,211	1,843	9,368	11,141
Side-roll	-8,300	3,984	2,986	998	9,298
High-pressure center pivot	-11,973	2,459	3,163	-704	11,269
Low-pressure center pivot	-4,561	7,217	2,219	4,998	9,559

1/ Variable costs, including fuel, are based on 1980 estimates. Investment costs are based on 1978 machinery prices.

Appendix table 28--Estimated changes in returns to land, labor, management, and risk in converting from diesel to propane pumping plants on a small farm 1/

Irrigation system	Returns with diesel power	Returns with propane power	Diesel motor ownership cost	Returns with propane power/ diesel engine ownership cost	Change in returns
			Dollars		
100-foot pumping lift:					
Gated pipe with reuse	13,594	14,737	1,131	13,606	12
Autogated pipe	13,876	14,757	574	14,183	307
Gated pipe without reuse	13,355	14,694	1,153	13,541	186
Ditch and siphon	14,441	15,657	1,145	14,512	71
300-foot pumping lift:					
Gated pipe with reuse	-627	1,804	2,165	-361	266
Autogated pipe	2,067	4,413	1,102	3,311	1,244
Gated pipe without reuse	-3,852	-955	2,206	-3,161	691
Ditch and siphon	-4,278	-1,280	2,191	-3,471	807

1/ Variable costs, including fuel, are based on 1980 estimates. Investment costs are based on 1978 machinery prices.

Appendix table 29--Estimated changes in returns to land, labor, management, and risk in converting from diesel to propane pumping plants on an intermediate size farm 1/

Irrigation system	Returns with diesel power	Returns with propane power	Diesel motor ownership cost	Returns with propane power/ diesel engine ownership cost	Change in returns
	Dollars				
100-foot pumping lift:					
Gated pipe with reuse	52,225	53,804	1,184	52,620	395
Autogated pipe	53,905	55,329	1,149	54,180	275
Big gun	29,161	32,892	2,201	30,691	1,530
High-pressure center pivot	41,179	42,910	1,709	41,201	22
Low-pressure center pivot	46,336	47,492	1,293	46,199	-137
300-foot pumping lift:					
Gated pipe with reuse	30,455	32,955	2,269	30,686	231
Autogated pipe	33,540	36,661	2,202	34,459	919
Big gun	7,585	8,314	3,401	4,913	-2,672
High-pressure center pivot	23,038	22,140	3,132	19,008	-4,030
Low-pressure center pivot	29,083	29,485	2,200	27,285	-1,798

1/ Variable costs, including fuel, are based on 1980 estimates. Investment costs are based on 1978 machinery prices.

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Appendix table 30--Estimated changes in returns to land, labor, management, and risk in converting from diesel to propane pumping plants on a large livestock farm 1/

Irrigation system	Returns with diesel power	Returns with propane power	Diesel motor ownership cost	Returns with propane power/ diesel engine ownership cost	Change in returns
			Dollars		
100-foot pumping lift:					
Gated pipe with reuse	23,332	25,629	1,731	23,898	566
Autogated pipe	23,455	25,017	965	24,052	597
Side-roll	17,737	20,450	1,702	18,748	1,011
High-pressure center pivot	10,069	12,607	1,677	10,930	861
Low-pressure center pivot	16,455	18,277	1,303	16,974	519
300-foot pumping lift:					
Gated pipe with reuse	-5,169	-154	3,310	-3,464	1,705
Autogated pipe	-1,773	1,737	1,843	-106	1,667
Side-roll	-8,300	-5,511	2,986	-8,497	-197
High-pressure center pivot	-11,973	-12,580	3,163	-15,743	-3,770
Low-pressure center pivot	-4,561	-3,600	2,219	-5,819	-1,258

1/ Variable costs, including fuel, are based on 1980 estimates. Investment costs are based on 1978 machinery prices.

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